UNITED STATES DEPARTMENT OF AGRICULTURE

**BULLETIN No. 885**

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. ▼ December 11, 1920

# THE BLACK FLY OF CITRUS AND OTHER SUBTROPICAL PLANTS

By

HARRY F. DIETZ, Entomological Inspector, Bureau of Entomology, United States Department of Agriculture, and JAMES ZETEK, Entomologist, the Panama Canal

## CONTENTS



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# THE BLACK FLY OF CITRUS AND OTHER SUBTROPICAL PLANTS.[1]

By HARRY F. DIETZ, *Entomological Inspector, Bureau of Entomology, United States Department of Agriculture*, and JAMES ZETEK, *Entomologist, The Panama Canal.*[2]

CONTENTS.



## INTRODUCTORY.

The black fly, *Aleurocanthus woglumi* Ashby, known also as the spiny citrus white fly and as the *mosca prieta,* is a tropical pest of the

[1] This work was done in cooperation with the Panama Canal, the second-named author being delegated to work with the bureau's representative. To the various departments and divisions of the Panama Canal which have aided and cooperated with them the authors are grateful. Special thanks are due the health department for providing laboratory space and facilities for carrying on the work, and the authors are indebted to the chief health officers, Col. H. C. Fisher and Lieut. Col. A. T. McCormack, and to the directors of the Board of Health laboratories, Drs. Oscar Teague, Wm. L. McFarland, and Lewis B. Bates, for their encouragement and advice from time to time.

The studies on the life history, habits, hosts, distribution, and control of the black fly in the Canal Zone and the adjoining parts of the Republic of Panama were begun in June, 1918, and the authors have been assisted in this work by Mr. Ignacio Molino, who, as entomological laboratory assistant, deserves special mention for the way he has carried on the work that has been assigned to him. Observations and experiments made by him are given full credit in the following pages.

Practically all the published literature relating to *Aleurocanthus woglumi* has been consulted and the data set forth compared with those obtained in the Canal Zone. Unpublished reports on this insect in the files of the Bureau of Entomology have been consulted, and much that was both interesting and helpful has been obtained in the discussions that one or both of the authors have had with Mr. J. R. Johnston, of the Comision de Sanidad Vegetal de Cuba, and Mr. Harold Morrison and Dr. A. C. Baker, of the Bureau of Entomology. Full use has been made of an unpublished report of Mr. Morrison on the status of the black fly in the West Indies.

[2] The arrangement of the authors' names is alphabetical and denotes neither seniority nor precedence.

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Old World that has made its appearance in the Tropics of the Americas. Its apparently rapid spread in the New World along with the fact that it now threatens to gain entrance into Florida from Cuba and Nassau makes it a pest of special interest from the plant quarantine point of view.

In August, 1917, Mr. Harold Morrison, the explorer in charge of the Mediterranean fruit fly investigations of the Bureau of Entomology, found the insect well established in Cristobal, Balboa, and Ancon in the Canal Zone, and in Colon and Panama in the Republic of Panama. Since the Canal Zone may be regarded as the crossroads of the New World's water traffic, a temporary field station was established at the Board of Health laboratory at Ancon to study the black fly and other tropical insect pests that might be carried by commerce to other parts of the Tropics or to the subtropical parts of the United States.

*Aleurocanthus woglumi* has several common names. It has been called the black fly, the citrus black fly, and the black scale in Jamaica and is known as the blue fly and the citrus blue fly in the Bahamas. In Florida it is known as the black fly. In literature it has also been referred to as the spiny citrus white fly in order to distinguish it from the common citrus white fly (*Dialeurodes citri* Ashmead). While this insect belongs to the family Aleurodidae, known as white flies, the term of white fly does not fit it, inasmuch as it is black or dusky in all stages. In Spanish countries the insect is known as *mosca prieta,* which means black fly. There is a minor objection to the use of the name black fly, inasmuch as it is the common designation of biting buffalo gnats, family Simuliidae.. Nevertheless, on account of the common and wide use of the name "black fly" for this aleurodid in English-speaking countries and of its Spanish equivalent in Spanish-speaking countries, it would probably be impossible now to secure the general adoption of any other name. There is little likelihood of any confusion arising in discussion or literature in the use of the term black fly for this insect as an enemy of citrus and other subtropical plants.

## THE SCIENTIFIC NAME OF THE INSECT AND TO WHOM IT SHOULD BE ACCREDITED.

The black fly was first described by Ashby (3)[3] in his article on the black scale or black fly. Although this description is entirely untechnical and is used merely in setting forth the stages in the life cycle, and although Ashby used Quaintance and Baker's manuscript name for the insect, and specifically states that this name should be credited to Quaintance, nevertheless, under the rules of the Inter-

[3] Figures in parentheses refer to "Literature cited," p. 53–55.

national Code of Nomenclature, Ashby's name must stand as the author of the species. Quaintance and Baker (31) have written the first and only technical description of *Aleurocanthus woglumi*, although the material that they had at hand did not permit their describing the first to third larval instars of this insect. The complete descriptions of all stages of the insect prepared by one of these authorities are included in this report.

## LITERATURE.

There are 33 references to *Aleurocanthus woglumi* in literature. Among the most important of these is the work of Johnston (16, 17), Cardin (7–11), and Hutson (12–15) in Cuba; Ashby (2, 3) and Ritchie (33, 34) in Jamaica; and that of Quaintance and Baker (31, 32) in the United States. Others who have contributed to the literature are Arango (1) in Cuba; Ballou (4) in Barbados; Bragdon (5), Montgomery (19), Newell (22–29), Pierce (30), and Watson (35) in the United States; McCormack (18, p. 30) in Panama; and Zetek (37) in Costa Rica. An unpublished work by Morrison in the files of the Bureau of Entomology covers his observations in Jamaica and Cuba and records his finding the insect for the first time in the Canal Zone. This report has been freely consulted and used by the authors.

No comprehensive publication on the black fly, however, has appeared to date.

A bibliography of the literature cited is given on pages 53 to 55.

## ORIGIN AND DISTRIBUTION.

*Aleurocanthus woglumi* unquestionably originated in the East Indies and from there it has been introduced into the Tropics of the New World, over which it is now spreading. It was first found in India by Maxwell-Lefroy in June, 1910. In the same year it was found in Manila, P. I., by George Compere. In October, 1910, R. S. Woglum, of the Bureau of Entomology, in search of parasites of the citrus white fly (*Dialeurodes citri* Ashmead), found *Aleurocanthus woglumi* at the Royal Botanical Gardens, Ceylon, and it is in his honor that the species is named. From November, 1910, to June, 1911, Woglum found this insect at the following places in India: Gujranwala; Kalimpong, Sikkim; Lahore and Nagpur, Central Province. In November, 1913, Mr. A. Rutherford added Peradeniya, Ceylon, to the Old World distribution of the black fly.

*Aleurocanthus woglumi* was first sent in to the Bureau of Entomology for determination from the New World in November, 1913, and February, 1914, by Col. C. Kitchner, from Half-Way, Jamaica. In May, 1914, S. F. Ashby, microbiologist of the Department of Agriculture of Jamaica, sent in specimens of this pest from Kingston, and

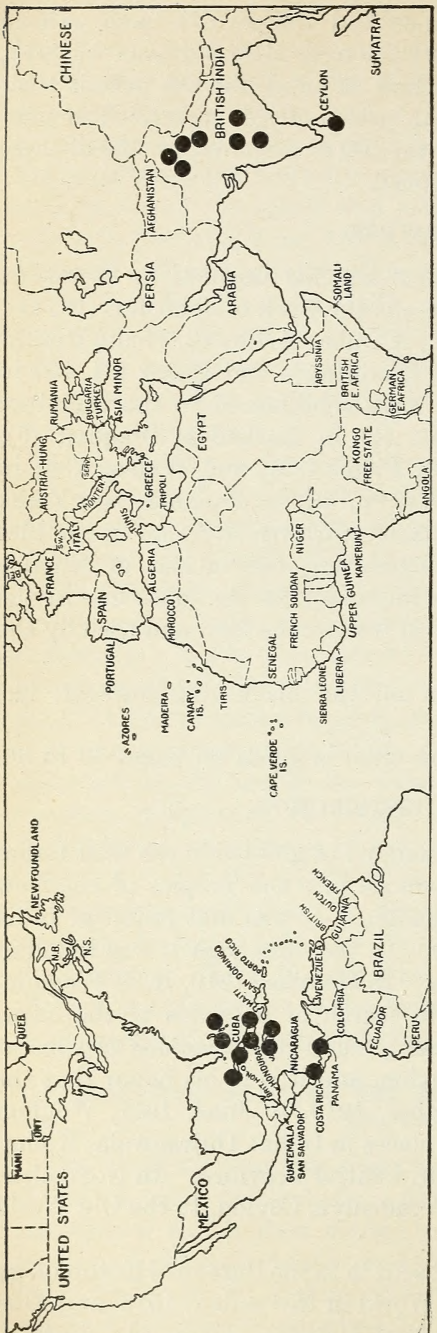



FIG. 1.—World distribution of the black fly (*Aleurocanthus woglumi*).

in 1915 he wrote two papers (2) and (3), indicating therein that it was rather widespread over the island of Jamaica. In February, 1916, Patricio Cardin, entomologist of the experiment station of Cuba, sent in specimens from Guantanamo, Cuba, and in the same month L. J. K. Brace sent in specimens from Nassau, New Providence, Bahama Islands. In 1917 Johnston (16, 17) showed that the insect occurred in Cuba, at Guantanamo and Habana. This same year Ritchie (34) states that "the entire island [Jamaica] is becoming generally involved." In an unpublished report of November, 1917, in the bureau files, Harold Morrison gives an account of the black fly in Jamaica and Cuba, and for the first time called attention to the fact that this insect was established in the Canal Zone and the adjoining parts of the Republic of Panama, having been found by him on citrus and mango trees in Cristobal, Ancon, and Balboa in the former place and in Colon and Panama in the latter, in August of that year. In the early part of 1918 Dr. W. M. Mann, of the Bureau of Entomology, found the pest in the vicinity of Santiago de Cuba, thereby establishing a new Cuban distribution record. In his explorations of the British West

Indies in 1918, Morrison did not find this pest in Barbados, Grenada, Tobago, Trinidad, or British Guiana. The British entomologists of these regions are fully acquainted with this insect and are carefully

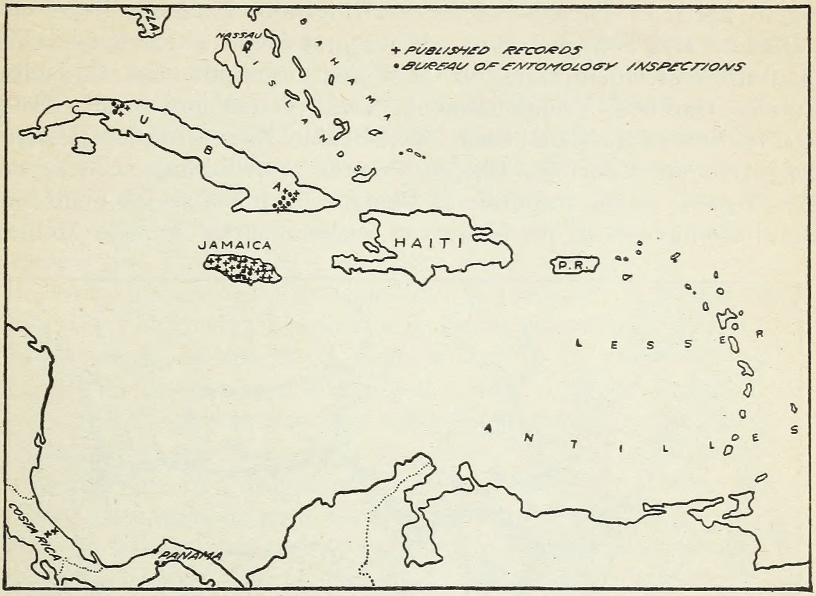



FIG. 2.—Distribution of the black fly in the West Indies.

watching for it. Therefore it is safe to assume that the black fly does not occur there at the present time. In his trip to the Virgin Islands in 1917, Morrison did not find it at any places visited by him

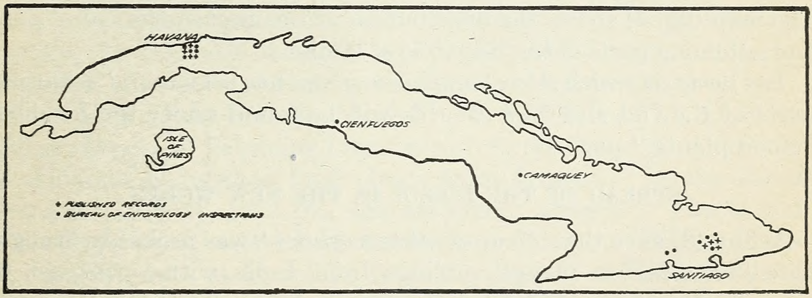



FIG. 3.—Distribution of the black fly in Cuba.

on the islands of St. Croix, St. John, or St. Thomas. Neither did he find it in Porto Rico in his inspections that year.

In 1919, Zetek (37) records for the first time the occurrence of the black fly in Costa Rica, having found it in the vicinity of Limon and as far inland as Peralta, on the Northern Railroad.

The maps show the distribution of the black fly in the world (fig. 1), in the West Indies (fig. 2), and in Cuba (fig. 3).

In the Canal Zone this insect has been found at Cristobal, Mount Hope, Gatun, Frijoles, Pedro Miguel, Miraflores, Corozal, Balboa, Palo Seco, and Ancon, and in the Republic of Panama it has been found in Colon, Panama (including the suburbs), the Las Sabanas region north of Panama as far as Rio Bajo, Panama Vieja (Old Panama), and Taboga Island. It was not found at the large citrus plantation at Juan Mina, or at Limon, Summit, Las Cascadas, Empire, Gamboa, Venado, Bracho, Mindi, Toro Point, France Field, or Coco Solo in the Canal Zone, or at Pueblo Neuvo, Matias Hernandez, Arraijan, Chorrera, Chepo, Pecora, or Almirante (Bocas del Toro region) in the Republic of Panama, at all of which points inspections have been made by the authors or by Ignacio Molino.

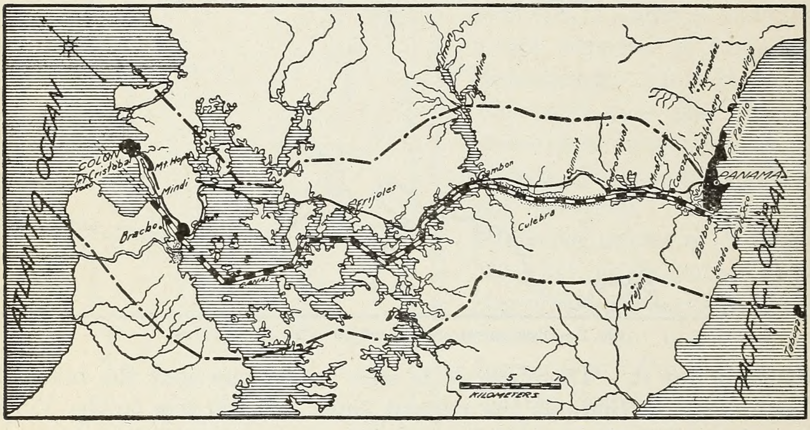



FIG. 4.—Distribution of the black fly in the Canal Zone and adjoining parts of the Republic of Panama.

The map (fig. 4) shows the distribution of this pest in the Canal Zone and adjoining parts of the Republic of Panama.

The hosts on which *Aleurocanthus woglumi* has been found in various parts of the Old and New Worlds will be found under the heading, "Food plants," page 14.

## SPREAD OF THE INSECT IN THE NEW WORLD.

Ashby (3) says that *Aleurocanthus woglumi* "was probably brought here [Jamaica] on mango cuttings from India within the last 20 years." Morrison, after his investigation of conditions in Jamaica, believes that "the pest has been introduced certainly within 10 years or even as late as 1910." There is no question that the insect was first introduced into Jamaica from India either on mango or some other host, and that from this focus in the New World it has spread to Nassau, New Providence, Bahama, the Guantanamo and Santiago de Cuba regions of Cuba, and the Canal Zone. The actual time of its introduction into any of these localities has not been determined.

If it is assumed that it was introduced into Jamaica within the last 10 or 12 years, then its spread from there to the places mentioned before has indeed been remarkably rapid, and it is merely a matter of a short time until it will occur throughout Cuba, the Bahamas, and the citrus-growing regions of Central and South America.

There is perhaps only one way that an insect like *Aleurocanthus woglumi* can be introduced from an infested region to an uninfested, suitable, far distant one and become established. This is on a well-infested host plant or parts thereof on which the leaves are allowed to remain, so packed that the various stages of the insect can continue their development throughout the journey, or at least withstand it. This is because there are several checks to its successful establishment: First, a high mortality of the individuals, especially in the early instars or at molting time, if subjected to adverse conditions, such as drying out or heavy rains; secondly, the fact that parthenogenesis occurs in *A. woglumi* just as in other white flies whose life history has been worked out; and thirdly, the fact that the larvæ are not vigorous crawlers and seldom get more than an inch away from the eggs from which they hatch. These factors are considered at length in a discussion of the life history of this insect.

When *Aleurocanthus woglumi* is favorably introduced into a new locality, however, there are several ways in which it may spread and become thoroughly established in a region. These methods are the natural and the artificial. The natural method includes: First, the natural flight or migration of the adults from infested to clean plants; secondly, the carriage of the adults and possibly larvæ by winds. The artificial method includes: First, the carrying of infested plants from one place to another either in the form of pot or specimen plants or in numbers as in the case of nursery stock or as cuttings; secondly, the carrying of adults on vehicles, trains, automobiles, or the clothes of persons passing or working among infested trees.

There is no doubt that the black fly has had at least a half dozen or more chances of becoming introduced into the Canal Zone through the shipment of infested food plants from Jamaica. In the Canal Record for July 31, 1912 (6), this statement appears: "Plants and shrubs have been received at Ancon from Director Wilder of the Botanical Gardens at Honolulu, from the director of Hope Gardens, Kingston, Jamaica, and from the Department of Agriculture in Washington, D. C." The Record gives a large list of plants, several of which have been found to be hosts of the insect, but unfortunately no mention is made of the origin of specific plants and the writers have been unable to trace any of the food plants mentioned in the list to Jamaica origin. The important point is that plants have been brought to Ancon from Jamaica as late as 1912 and undoubtedly later, and Ancon, Balboa, and Panama seem to be the most heavily

and thoroughly infested parts of the Canal Zone and closely adjoining parts of the Republic of Panama. In surveys made by the authors at Ancon, Balboa, and Panama, not a single citrus tree has been found entirely free from *woglumi*, and at least 70 per cent of all the mangoes have been found infested, about 10 per cent of these being heavily infested. Practically all the citrus trees in these towns are limes used for ornamental purposes in gardens, in lawns, or along the streets, and fully 50 per cent of such trees are what might be called heavily infested.

It has also been determined by a survey of the Las Sabanas region, which lies to the north of Panama, that several wealthy Panamanians have themselves introduced plants from Jamaica to that region.

There is no regulation of any kind outside of the ordinary customs regulations governing the introduction of plants to either the Canal Zone or the Republic of Panama from any part of the world. Neither are there any regulations governing the free movement of plants within that area. Hence, it is no uncommon thing to see passengers on vessels from various parts of South America bringing living plants into the Canal Zone or the Republic of Panama, to friends or for their own use. Neither is it an uncommon thing to see passengers from the West Indies or other parts of Central America bringing in plants. These passengers are often residents of the Canal Zone or Republic of Panama and bring the plants as a remembrance of their visit or because of the fact that such plants, if they are fruit trees, bear more delicious fruits than do closely related ones in the Canal Zone or Panama. It is common knowledge that the West Indian negroes are great lovers of plants and it has been repeatedly observed by the writers in their visits to Cristobal that even negro workmen carry plants with them when they leave or arrive in the Canal Zone.

From the foregoing it is apparent that the original infestations of *Aleurocanthus woglumi* occurring at the terminals of the Panama Canal in the Canal Zone and Republic of Panama may be the result of the introduction of more than one lot of infested host plants from Jamaica, and it is probable that the first introduction took place as early as 1912.

Whether the original infestation in the Cristobal-Colon section was a separate introduction or whether it preceded or succeeded the Ancon-Balboa-Panama one will never be known definitely. It must be remembered that the grounds of Ancon Hospital were a sort of botanical garden in the days of the French and remained as such in the early part of the American régime, their place finally being taken by what is now Ancon Nursery. It is quite possible, therefore, that the infested plants might have been sent to Cristobal and Colon from Ancon.

That this insect has been and is freely spread about on citrus nursery stock is shown by the fact that young lime trees in Ancon Nursery were found to be infested with it. Further numerous cases have been found in Panama where persons have grown young citrus trees of various kinds, mostly oranges and tangerines, in the city from seeds and then taken the plants, when they had grown to be a foot or more high, to their farms in the Las Sabanas region or to Taboga Island, which is 12 miles from the mainland in Panama Bay. Indeed, the heavy infestation on this island can not be accounted for in any other way except that infested food plants of the black fly were brought there from the mainland, and from these as a focus the insect has spread by natural means. Unquestionably the infestations at Mount Hope, Gatun, Pedro Miguel, Corozal, and Palo Seco were started in the same way.

At Frijoles and Miraflores the infestations are in all probability "train borne." At the former place lime trees growing by the station and within 25 feet of the railroad track, which were carefully examined in October, 1918, and found to be uninfested, were found slightly infested in April, 1919. In the Canal Zone, the Panama Railroad supplying its commissaries runs its freight cars onto sidings bordered with limes infested with the black fly. This is particularly true at Ancon. Hence adults might readily fly onto or into such freight cars and fly off at a place like Frijoles where practically all trains stop. The only trees found infested in the region were five limes by the station; large oranges and limes around the village, and younger limes at the entrance of the avocado plantation, both of which are at least 150 feet away from the railroad, being free from the pest. The same condition obtained at Miraflores, where two lime trees of a double row of 108 limes leading from the road west of Miraflores Tunnel to the filtration plant were found lightly infested. These trees were the two nearest the railroad and within 75 feet of it. In traveling on the passenger trains from Panama City to various points along the main line, the writers and Mr. Molino have inspected the windows for the adults of *Aleurocanthus woglumi*, and although several species of larger insects have been found, at no time has a single adult of *woglumi* been seen. However, on such trips persons have been seen taking flowers and plants from Colon and Panama to points along the railroad in the Canal Zone or vice versa. The foregoing method may offer a possibility of the introduction of this insect into Florida from Cuba, as Newell (25) has pointed out. Whether the insects could become successfully established depends on the numbers of females that are introduced and whether or not these females have been fertilized. Its successful establishment in Florida will depend also on the adapta-

bility of the insect to climatic conditions that vary considerably from those in which it is now known to occur.

That the spread of this insect in the Ancon-Balboa-Panama, the Cristobal-Colon, the Las Sabanas, and Taboga Island regions is entirely due to the widespread dissemination of infested food plants is not the writers' idea. Doubtless much of the dispersion has been due to this method. But there is sufficient evidence that the infestation does spread to uninfested hosts through the flight or migration of the adults. This has been shown by numerous field-inspection trips. The infestation of large trees such as mango, sapodilla, lime, and orange in these regions, many of them much older than the introduction of *woglumi*, would show this.

At Taboga Island the spread is definitely from the village of Taboga along the shore line to the east and west and to the south following the paths up the steep "backbone" ridge of the island. This spread is most probably a question of the flight of the adults, and the rate at which it is taking place on coffee plants along the creek leading from the village to the south and opposite side of the island substantiates this opinion.

That the adults do fly or migrate is shown by the following facts: There is often a decided variation in the number of adults on the young growth in the morning and evening inspections of the same trees, indicating a migration of the adults either at dusk or in the early morning. On the evening of July 29, 1918, Zetek found several adults in his house, indicating that the migration takes place at dusk; adults have been taken in spider webs 75 to 100 feet away from the nearest infested food plant; the migration from an infested food plant to a noninfested one has been demonstrated in Panama; and finally, the observations at Corozal indicate that a flight of 400 feet is possible. The first point mentioned is shown by the seasonal abundance records for a year, observations on three different lots of trees being made three times a day. Adults caught in spider webs were commonly observed in a garden next to the board of health laboratory during the months of May and June, 1919. Likewise it was found that the adults were flying from heavily infested lime trees to young trees of guayabanon (*Annona squamosa*) and guava (*Psidium guajava*) about 60 feet away and set out in nursery rows. Various stages of the pest were later found on the guava, but the annona here remained free from all stages except the adults.

In the yard of Ignacio Molino in Panama early in April, owing to a heavy infestation of *Aleurocanthus woglumi*, two orange trees were "dehorned," every leaf and green shoot being cut off of them. Early in May, nine new shoots were growing from adventitious buds and on these were found adults of the black fly and egg spirals. A careful survey of all the plants in the yard was made. At a dis-

tance of 30 feet from these orange trees a young palm, *Eleais melanococca*, was found to be lightly infested and adults were seen flying away from it toward the orange trees when disturbed. Hence, it is evident that this palm was the source of reinfestation of the orange.

At Corozal in October, 1918, four lime trees in front of what was once the old post office (house 543, now used as quarters for attendants at Corozal Asylum) were found lightly infested with *A. woglumi*. Across the road, behind the houses opposite Corozal Asylum, on a long open lawn space, was a row of 29 lime trees, none of them infested, the nearest being at least 300 feet from the four infested trees. After the first week of heavy rains following the dry season (Apr. 24, 1919) all trees were reinspected. The infested trees showed a decidedly heavier infestation and of the row of limes uninfested in October, 1918, trees Nos. 9, 10, 20, 25, 27, 28, and 29 were found infested. Tree No. 1 was the farthest away (about 900 feet) from the source of infestation and trees Nos. 20 to 29 the nearest (200 to 300 feet away) to it. Trees Nos. 20 to 25 were almost directly opposite the originally infested trees. That this was a recent infestation was shown by the fact that no individuals were found beyond the pupal stage and no adults had emerged from any of the pupæ found. In July this row of trees was again examined and trees Nos. 9, 10, 11, 12, 18, 20, 23, 25, and 29 were found infested and the infestation was increasing. It is evident that the infestation of numbers 11 and 12 came from trees Nos. 9 and 10 and that of 18 came from tree No. 20. The infestation on Nos. 27 and 28 had died out for some reason. Here we have an infestation due directly to the flight of adults, the longest flight being about 700 feet and the least 200 feet.

It has been noted in bringing adults into the laboratory on shoots on which they had gathered in abundance in the field, that when such shoots wilted the adults would leave them and fly out of the screened windows, a case of forced migration guided by positive phototropism.

Likewise in working around trees on which adults were clustered in the late afternoon it has been observed that when disturbed many of the adults take to flight and, instead of merely flying off a short distance and returning to the trees as they often do, a large number would disappear permanently.

No observations have been made as to whether or not the insect is carried by the wind. Nor has there been seen any such migration as Morrill and Back (21, p. 44–48) have described as taking place in the case of the citrus white fly (*Dialeurodes citri* Ashmead). This is probably due to the fact that no large and heavily infested citrus

groves were available for observation either in the Canal Zone or near-by portions of the Republic of Panama.

Infestations started by adults carried on vehicles or on the clothing of men working among infested trees and then going to uninfested ones have not been seen. However, the first-mentioned writer, after making observations on trees on which adults were common, has carried stray individuals on his clothing at least 3,000 feet.

The rate of spread or infestation on infested trees has been determined in the following ways: First, taking a shoot that is beginning to grow and watching the number of new spirals laid on the leaves of said shoot; second, taking shoots at the beginning of the rainy season and checking the number of egg spirals laid on the leaves of said shoots. In this latter method shoots of the preceding season were selected and the rate of infestation on this mature growth as well as on new growth that started from the tip of the mature growth was determined by the number of eggs laid on such growth.

The first method is illustrated by the record kept on a young shoot of orange from October 23 to November 17, 1918, or from the time that this shoot had grown from 3.5 to 11 inches long. No eggs were laid before November 5 and the leaves are numbered from the bottom of the growth upward.

TABLE I.—*Number of egg spirals laid by the black fly on young orange shoot.*

| Leaf No. | First spirals laid. | Number. | New spirals laid on November— | | | | | | | | | | | | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | |
| 1 | Nov. 5 | 2 | 3 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | ...... | ...... | ...... | ...... | 17 |
| 2 | Nov. 6 | 3 | 3 | 3 | 0 | 1 | 1 | 3 | 1 | 2 | 2 | 1 | ...... | ...... | 17 |
| 3 | Nov. 8 | 3 | 0 | 0 | 3 | 10 | 0 | 0 | 0 | 2 | 2 | 2 | ...... | ...... | 19 |
| 4 | ...do.... | 2 | 0 | 0 | 2 | 5 | 1 | 2 | 0 | 1 | ...... | ...... | ...... | ...... | 11 |
| 5 | Nov. 9 | 4 | 0 | 0 | 0 | 4 | 0 | 2 | 3 | 1 | 4 | ...... | ...... | ...... | 14 |
| 6 | Nov. 12 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | ...... | ...... | ...... | ...... | 7 |
| 7 | Nov. 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | ...... | ...... | ...... | ...... | 2 |
| 8 | ...do.... | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | ...... | ...... | ...... | ...... | 1 |
| 9 | Nov. 14 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | ...... | ...... | ...... | 1 |
| 10 | Nov. 13 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | ...... | ...... | ...... | ...... | 1 |
| 11 | ........ | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 0 |
| 12 | Nov. 14 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | ...... | ...... | ...... | 1 |
| 13 | Nov. 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | ...... | ...... | 1 |

No eggs were laid on this shoot between November 15 and December 1; observations, therefore, were discontinued. In this case it must be borne in mind that the old growth of this tree was heavily infested with *A. woglumi* in all stages of development, and that the adults were abundant on the young growth up until November 17, after which a decided dropping off took place, so that during the period from November 23 to December 23 very few adults were present on the entire tree. On April 8, which is just at the end of the dry season, the eggs on a 19-inch long shoot were counted and found

to be as follows, the count of the leaves being made from the bottom to the top of the shoot.

TABLE II.—*Eggs of black fly on 19-inch orange shoot at end of dry season.*

| Leaf No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Egg spirals | 0 | 0 | 3 | 2 | 1 | 2 | 4 | 1 | 0 | 1 | 5 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0. |

This shows that the rate of the infestation of young growth on a tree is dependent (1) on the degree of infestation of the older leaves on the tree which, in a large measure, determines the number of adults present on the young growth; (2) on the season. This is discussed further under the heading, "Seasonal history," page 42. For an idea of this tree at the times these counts were made see the photographs (Pl. I).

That the degree of infestation or rate of spread on a given plant is determined by the species of plant is shown by Tables III and IV for the lime trees at Ancon.

TABLE III.—*New egg spirals of the black fly on old and new lime leaves, experiment No. 8, 1919.*

| Leaf No. | May 17. | May 24. | May 31. | June 7. | June 14. | June 21. | June 28. | July 5. |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 2 | 1 | 0 | 1 | 3 | 1 | 0 | 3 | 2 |
| 3 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 0 |
| 4 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 |
| 5 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 6 | 0 | 0 | 3 | 0 | 3 | (?)3 | 4 | 0 |
| 7 | 1 | 1 | 0 | 1 | 0 | 2 | 0 | 0 |
| 8 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 1 |
| A[1] | 0 | 1 | 3 | 2 | 2 | 0 | 0 | 2 |
| B | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 |
| C | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| D | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| E | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| Total | 2 | 5 | 14 | 10 | 11 | 7 | 7 | 7 |

[1] The leaves on the new growth were lettered A, B, etc., upward from the junction of the new growth with the old and the leaves of the old growth were numbered 1, 2, etc., upward, starting with the junction of a much older shoot or branch.

The observations on this shoot were begun on April 10, 1919, at the end of a dry season, the rainy season beginning on April 13.

TABLE IV.—*New egg spirals of the black fly on old and new lime leaves, experiment 9, 1919.*

| Leaf No.[1] | Apr. 17. | Apr. 26. | May 3. | May 10. | May 17. | May 24. | May 31. | June 7. | June 14. | June 21. | June 27.[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 1 |
| 2 | 2 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 7 | 1 | 1 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| A[3] | ........ | ........ | ........ | ........ | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| B | ........ | ........ | ........ | ........ | 0 | 0 | 3 | 1 | 4 | 0 | 0 |
| C | ........ | ........ | ........ | ........ | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| D | ........ | ........ | ........ | ........ | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| E | ........ | ........ | ........ | ........ | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| F | ........ | ........ | ........ | ........ | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| G | ........ | ........ | ........ | ........ | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| H | ........ | ........ | ........ | ........ | 0 | 2 | 0 | 0 | 0 | 0 | 1 |
| I | ........ | ........ | ........ | ........ | 0 | 2 | 0 | 5 | 2 | 0 | 1 |
| J | ........ | ........ | ........ | ........ | 0 | 1 | 1 | 5 | 1 | 1 | 0 |

[1] In this experiment the lettering of the young growth and the numbering of the old are the same as in the preceding.
[2] This experiment was accidentally destroyed by the pruning of the trees on June 30.
[3] This shoot started to grow on May 3, but no eggs were observed on it until May 24.

These 2 tables are characteristic of 30 that were kept on lime trees. The field observations at Ancon, Balboa, and Cristobal indicate that an infestation of *Aleurocanthus woglumi* on this host, while persistent and oftentimes heavy, does not progress with the rapidity that it does on such hosts as grapefruit, orange, and tangerine. Further discussion of this point is given under "Injury," page 18. In this connection see Plates I, II, and III.

Many of the trees along the roads and on the lawns in Ancon came to the Canal Zone in 1916 as nursery stock from Aguadulce, Republic of Panama, and all those trees are more or less uniformly infested, indicating either that they were all infested at the time that they were set out, or that they became so shortly thereafter through eggs laid on them by migrating adults. It has recently (Sept. 15, 1919) been ascertained, however, through a letter accompanied by specimens, that *Aleurocanthus woglumi* is firmly established at Aguadulce. This would indicate that the trees were infested at the time they were set out, and if the rate at which the infestation on the trees is progressing is any criterion by which to judge the time that *woglumi* has been present in the Canal Zone, it is safe to say that it was first introduced there not later than 1912, for these lime trees must yet, after three years, be regarded as only moderately infested. On this basis and assuming that it came to the Canal Zone during or before 1912, then it has been in Jamaica 15 or more years or at least since before 1910.

In Jamaica and Cuba the insect's spread has paralleled that in the Canal Zone. In the former place after being introduced into the vicinity of Kingston it spread around this locality by both natural and artificial means, but its dispersion to the more distant parts of the island was unquestionably by means of infested food plants. Once it was introduced into a new locality its spread there was by both natural and artificial means. In Cuba it was first introduced into the Guantanamo region on infested plants from Jamaica and its spread took place by both natural and artificial means. From Guantanamo it was carried to Havana on infested plants, where its spread was again by natural and artificial means. Whether or not the infestation in the region of Santiago de la Cuba is a separate introduction of infested plants from Jamaica or whether it is traceable to infested plants from the Guantanamo region is not known.

## FOOD PLANTS.

The food plants of the black fly fall under the three following heads: (1) The favorite or preferred food plants, i. e., those that become heavily infested with the insect and on which complete development from egg to adult takes place; (2) the occasional food plants, i. e., those on which complete development of the insect can and does

take place, but which apparently do not become heavily infested with it; (3) supplemental food plants, or those which the adults may visit and from which they may obtain food, but on which either they do not lay eggs or, if they do, complete development does not take place. It must be borne in mind that these three classes are not clear-cut ones but merge into one another. They are based on the writers' observations in the Canal Zone.

In this region the favorite food plants in the order named appear to be *Ardisia revoluta*, the oranges (both sweet and sour), grapefruit, lemon, lime, and mango. No large areas of coffee in infested regions have been found in our surveys and little can be said about this host from our experience, though the writers in Cuba and Jamaica are agreed that it comes before mango in the list.

Among the occasional hosts may be included such plants as sapodilla (*Achras sapota*), oil nut palm (*Eleais melanococca*), Cashew apple (*Anacardium occidentale*), sugar apple (*Annona squamosa*), *Eugenia malaccensis*, mamon (*Melicocca bijuga*), guava (*Psidium guajava*), and mamei (*Lucuma mammosa*). With the exception of the favorite or preferred food plants these constitute an important means by which the insect may be spread on nursery stock or on individual plants. These occasional food plants may and probably will constitute an important source of reinfestation where control of the black fly, especially on citrus, is undertaken. This has been shown in the case of the oil nut palm (*Eleais melanococca*) under the heading "Spread of the insect," on pages 10–11.

Among the supplemental food plants are the orange jessamine (*Chalcas exotica*), Barbados cherry (*Malpighia glabra*), and crape myrtle (*Lagerstroemia indica*). These may serve merely as occasional food plants for the adults or as congregating places, but why the adults should congregate on them in large numbers, even in the presence of their favorite food plants, and not lay eggs, as has been observed in the case of the last two mentioned plants, we will not attempt to explain. That it does not always pay to "jump at conclusions" or to make broad generalizations regarding the food plants of a polyphagous insect like the black fly is shown in the case of the orange jessamine. In the first place, it is a rutaceous plant, a citrus relative, and one would naturally expect it to fall into first or second class of food plants. That it is merely a supplemental host has been proved, not only by the repeated examination of a large number of plants, but also by attempting to rear the insect on it. Never has a single specimen of *Aleurocanthus woglumi* beyond the first instar been found on this plant, though egg spirals are laid in abundance on it and adults often collect in numbers on its younger growth. Although the larvæ are able to attach themselves to the leaves, invariably they die and fall off before reaching the first molt. Hence,

simply because the adults of *woglumi* gather on a plant or because eggs and the early stage larvæ have been found on it, the conclusion that such a plant is an important host of the insect does not necessarily follow. The only criterion as to whether a certain species is in reality a favorite or an occasional food plant is the finding of insects in all stages of development on it.

*Aleurocanthus woglumi* Ashby has been recorded from 75 different food plants or hosts. These are distributed among 30 plant families.

The following table shows the plants on which it has been found, the family to which the plants belong, and the place and person who collected it. The plants on which it has been found in the Canal Zone and the adjoining parts of the Republic of Panama are marked with an asterisk and a number, the number indicating the class of the food plant as previously discussed. The writers do not presume to say to which class the food plants recorded by other authors belong, but such plants as avocado, hibiscus, various begonias, papaya, croton, plantain, pomegranate, star apple, and coral vine have been repeatedly examined in the Canal Zone and Republic of Panama, and in no case have any stages of the black fly been found on any of them so far. The banana is an example of a plant that is on the border line between the second and third classes. Out of at least a hundred plants that have been carefully examined only three colonies of the insect have ever been found on this host, and those were on a plant growing within 6 feet of a mango heavily infested with the insect.

TABLE V.—*Host plants of the black fly (Aleurocanthus woglumi).*

| Scientific botanical name.[1] | Family. | Common name (Spanish and English). | Locality and by whom reported.[2] |
|---|---|---|---|
| *Acalypha linneolata? (lanceolata* Willd). | Euphorbiaceae | acalypha | Guantanamo, Cuba.—C. J. & H. |
| *Achras sapota* Linn. (x-2) | Sapotaceae | nispero, sapote | Canal Zone, Panama, R. P.—D. & Z. |
| | | sapodilla | Cuba (Habana and Guantanamo).—C. J. & H. |
| *Anacardium occidentale* Linn. (x-2). | Anacardiaceae | marañon | Guantanamo, Cuba.—C. J. & H. |
| | | cashew apple | Las Sabanas, R. P.—M. & Z. |
| *Annona cherimola* Mill | Annonaceae | chirimoya Jamaica apple | Guantanamo, Cuba.—C. J. & H. |
| *Annona muricata* Linn | do | anon manteca soursop | Do. |
| *Annona squamosa* Linn. (x-2). | do | anon | Guantanamo, Cuba.—C. J. & H. |
| | | sugar apple, sweetsop | Las Sabanas, R. P.—M. & Z. |
| *Annona* sp. (x-2) | do | | Canal Zone.—D. & M. |
| *Antigonon leptopus* Hook | Polygonaceae | rosa de montaña, coralito. coral vine, love's chain. | Guantanamo, Cuba.—C. J. & H. |
| *Ardisia revoluta* H. B. & K. (x-1). | Myrsinaceae | fruta de pava | Las Sabanas, R. P.—M. & Z. |
| *Bassia latifolia* Roxb | Sapotaceae | mahwa | Jamaica.—R. |
| *Begonia* sp | Begoniaceae | begonia | Guantanamo, Cuba.—C. J. & H. |
| *Capparis pedunculosa* Wall | Capparidaceae | caper-bush | Royal Botanical Garden, Ceylon.—W. Q. & B. |
| *Capparis roxburghi* DC | do | do | Do. |
| *Carica papaya* Linn | Papayaceae | fruta bomba, papaya papaya | Guantanamo, Cuba.—C. J. & H. |

For footnotes 1 and 2 see page 18.

TABLE V.—*Host plants of the black fly* (*Aleurocanthus woglumi*)—Continued.

| Scientific botanical name. | Family. | Common name (Spanish and English). | Locality and by whom reported.[2] |
|---|---|---|---|
| *Cestrum diurnum* Linn. | Solanaceae | galan de dia; day-blooming jessamine. | Guantanamo, Cuba.—C. J. & H. |
| *Cestrum nocturnum* Linn. | do | galan de noche; night-blooming jessamine. | Do. Jamaica.—A. Q. & B. |
| *Chalcas exotica* Millsp. (x-3). | Rutaceae | orange jessamine | Canal Zone and Panama, R. P.—D. & Z. |
| *Chrysophyllum cainito* Linn. | Sapotaceae | star apple | Guantanamo, Cuba.—H. |
| *Citrus aurantifolia* Swingle (*limetta* auct.) (x-1). | Rutaceae | lima; lime | Canal Zone, Panama, and Taboga, R. P.—D. & Z. Cuba (Guantanamo and Habana).—C. J. & H. |
| *Citrus aurantium* Linn. (x-1) | do | naranjo; sour orange | Canal Zone, Panama, R. P. ?—D. & Z. Cuba (Guantanamo and Habana).—C. J. & H. |
| *Citrus grandis* Osbeck (*decumana* Linn.) (x-1). | do | toronja; grapefruit | Canal Zone, Panama, and Taboga, R. P.—D. & Z. Cuba (Guantanamo and Habana).—C. J. & H. |
| *Citrus limonia* Osbeck (x-1). | do | limon, limonero; lemon | Canal Zone ?, Panama, R. P.—D. & Z. Cuba (Habana and Guantanamo).—C. J. & H. |
| *Citrus medica* Linn. | do | cidro; citron | Cuba (Guantanamo and Habana).—C. J. & H. |
| *Citrus nobilis deliciosa* Swingle (x-1). | do | tangerino; tangerine | Panama, R. P.—D. & Z. Santiago, Cuba.—Mann. |
| *Citrus sinensis* Osbeck (x-1). | do | naranjo; sweet orange | Canal Zone, Panama, and Taboga, R. P.—D. & Z. |
| *Citrus* spp | do | not specified | Jamaica.—A. Q. & B. India (Lahore, Gujranwala, Kalimpong, Sikkim, Nagpur) (C. P.).—W. Q. & B. |
| *Citrus* sp. not specified | do | orange | India.—M. Q. & B., Manila, P. I.—Comp. Q. & B., Nassau, N. P. Bahama.—Brace, Q. & B. Cuba, Santiago.—Mann. |
| *Citrus* sp. not specified | do | lemon | Santiago, Cuba.—Mann. |
| *Clausena lansium* Skeels (*Clausena wampi* Oliv.). | do | wampie | Jamaica.—R. |
| *Coffea arabica* Linn. (x-1) | Rubiaceae | cafeto; coffee | Cuba (Guantanamo and Habana).—C. J. & H. Jamaica.—A. & R., Taboga, R. P.—D. & Z. Las Sabanas, R. P.—M. & Z. |
| *Cordia alba* Roem. and Schult. | Boraginaceae | uvita o goma; cordia | Cuba (Guantanamo).—C. J. & H. |
| *Cordia* sp | do | do | Do. |
| *Crescentia cujete* Linn. | Bignoniaceae | güira; calabash, gourd tree | Do. |
| *Croton* sp., probably Codiaeum referred to. | Euphorbiaceae | croton; croton | Do. |
| *Cupania cubensis* (*Blighia sapida* Kon.) | Sapindaceae | quarana; akee | Do. |
| *Eleais melanococca* Gaertn. (x-2). | Palmaceae | oil nut palm | Panama, R. P., Cristobal, C. Z.—D. & M. |
| *Eugenia jambos* Linn. (x-2). | Myrtaceae | pomarosa; rose apple | Las Sabanas, R. P.—M. & Z. |
| *Eugenia malaccensis* Linn. (x-1 or 2). | do | manzana de Tahiti; large-fruited rose apple | Do. |
| *Guaicum officinale* Linn. | Zygophyllaceae | lignum-vitae | Jamaica.—A. |
| *Guazuma tomentosa* Knuth. | Sterculiaceae | guasima, guacima | Cuba (Guantanamo).—C. J. & H. |
| *Hibiscus rosa-chinensis* Linn. | Malvaceae | Chinese hibiscus | Do. |
| *Hibiscus schizopetalus* Hook. | do | farolito chino; hibiscus | Do. |
| *Ixora thwaitesii* Hook (x-3). | Rubiaceae | bouquet de novia | Canal Zone.—D. & M. |
| *Kurrimia ceylanica* Arn. | Celastraceae | | Peradeniya, Ceylon.—Ruth. Q. & B. |
| *Laurus nobilis* Linn. | Lauraceae | laurel comun; laurel, sweet bay | Cuba (Guantanamo).—C. J. & H. |
| *Lagerstroemia indica* Linn. (x-3). | Lythraceae | crape myrtle | Canal Zone, Las Sabanas, R. P.—D. & M. |
| *Lucuma mammosa* Gaertn. (x-2). | Sapotaceae | mamey, mamey de tierra, mamei; mamei, mamey sapote | Cuba (Guantanamo and Habana).—C. J. & H. Las Sabanas, R. P.—M. & Z. |
| *Lucuma nervosa* A. DC. (x-2). | do | canistel; egg-fruit, canistel | Do. |

For footnotes 1 and 2 see page 18.

TABLE V.—*Host plants of the black fly (Aleurocanthus woglumi)*—Continued.

| Scientific botanical name.[1] | Family. | Common name (Spanish and English). | Locality and by whom reported.[2] |
|---|---|---|---|
| *Malpighia glabra* Linn. (x-3) | Malpighiaceae | cereza; Barbados cherry | Cuba (Guantanamo and Habana).—C. J. & H. Las Sabanas, R. P.—M. & Z. |
| *Melicocca bijuga* Linn. (x-2) | Sapindaceae | mamoncillo, mamon; Spanish lime | Cuba (Guantanamo and Habana).—C. J. & H. Las Sabanas, R. P.—M. & Z. |
| *Mangifera indica* Linn. (x-1) | Anacardiaceae | mango; mango | Canal Zone, Panama, Colon, Taboga, R. P.—D. & Z. Cuba (Guantanamo and Habana).—C. J. & H. Santiago, Mann; Jamaica.—A. & R. |
| *Morus* sp | Moraceae | mulberry | Lahore, India.—W. Q. & B. |
| *Musa paradisiaca* Linn | Scitaminaceae (Musaceae). | platano macho; plantain, cooking banana | Cuba (Guantanamo).—C. J. & H. |
| *Musa sapientum* Linn. (x-2) | do | guineo; banana | Canal Zone.—D. Z. & M. |
| *Passiflora edulis* Sims, probably referring to *P. quadrangularis* Linn. as well). | Passifloraceae | granadillo; maypop, passion flower | Cuba (Guantanamo).—C. J. & H. |
| *Persea gratissima* Gaertn | Lauraceae | aguacate; avocado, alligator pear | Cuba (Guantanamo and Habana).—C. J. & H. |
| *Psidium guajava* Linn (x-2) | Myrtaceae | guayabo, guayaba; guava | Cuba (Guantanamo and Habana).—C. J. & H. Canal Zone, Las Sabanas.—D. & M. |
| *Punica granatum* Linn | Punicaceae | granado; pomegranate | Cuba (Guantanamo and Habana).—C. J. & H. |
| *Salacia reticulata* Wight | Celastraceae | | Ceylon (Peradeniya).—Ruth. Q. & B. |
| *Tabernaemontana coronaria* Willd. | Apocynaceae | jasmin de montaña; crape jasmine, E. Indian rosebay. | Cuba (Guantanamo).—C. J. & H. |
| *Triphasia aurantiola* Lour | Rutaceae | limoncillo | Cuba (Guantanamo and Habana).—C. J. & H. |
| *Trichilia spondioides* Jacq | Meliaceae | jubaban | Cuba (Guantanamo).—C. J. & H. |
| *Wallenia laurifolia* Sw | Myrsinaceae | casmagua | Cuba (Guantanamo and Habana).—C. J. & H. |
| Plants of uncertain identity | | jasmin de candelero; jasmine | Cuba (Guantanamo).—C. J. & H. |
| | | jasmin de Persia; jasmine | Do. |
| | | manzana de rosa; rose apple? | Cuba (Guantanamo and Habana).—C. J. & H. |
| | | palma de abanico; travelers' palm | Cuba (Guantanamo).—C. J. & H. |
| | | unknown tree | India.—W. Q. & B. |

[1] KEY TO NUMBERS.

x-1, x-2, and x-3 refer to the class to which the food plant belongs, x-1 being favorite or preferred food plant, x-2 occasional food plant, and x-3 supplemental food plant, for a discussion of which see text, p. 14-18.

[2] KEY TO INITIALS.

A.—Ashby, S. F.
[a] A. Q. & B.—Ashby, S. F., Quaintance, A. L., and Baker, A. C.
[a] Brace, Q. & B.—Brace, L. J. K., Quaintance, A. L., and Baker, A. C. C. J. & H.—Cardin, Patricio; Johnston, J. R., and Hutson, J. C.
[a] Comp. Q. & B.—Compere, George, Quaintance, A. L., and Baker, A. C. D. & M.—Dietz, H. F., and Molino, Ignacio. D. & Z.—Dietz, H. F., and Zetek, James. Mann.—Mann, W. M.
[a] M. Q. & B.—Maxwell-Lefroy, Quaintance, A. L., and Baker, A. C. M. & Z.—Molino, Ignacio, and Zetek, James. R.—Ritchie, Archibald H.
[a] Ruth. Q. & B.—Rutherford, A., Quaintance, A. L., and Baker, A. C.
[a] W. Q. & B.—Woglum, R. S., Quaintance, A. L., and Baker, A. C.
[a] In the report of the hosts credited to Quaintance and Baker the first named person in every case refers to the collector of the material.

## INJURY.

Much has been written about the injury caused by the black fly to its favorite or preferred food plants. It has also been said that it only takes 20 months for this insect to increase to such numbers that it will kill its hosts, and "that an infestation of the black fly is invariably accompanied by rapidly-increasing scale infestation so that the life of an infested tree is necessarily short" (25). Furthermore, it

has been intimated by some writers that the black fly is an insect that can not be controlled except by such radical measures as were of necessity used in the eradication of citrus canker.

Careful attention, therefore, was given this phase of the problem by the writers. In order to determine definitely the amount of injury done, numerous inspections and reinspections of trees were made. Daily observations were made for a year on a row of lime trees, and the condition of these trees in October, 1918, and April, 1919, is shown in Plate II, figure 2, and Plate III, figure 2. Plate III, figure 1, shows the degree of infestation, which seemed to be at more or less of a standstill throughout this time, and there was practically no development of the black fly on these trees during the dry season. No appreciable injury was done to the trees during the year from June, 1918, to June, 1919.

As a check on these lime trees an equal number growing thickly together in a hillside garden near the Board of Health laboratory was selected. Plates V and VI show the degree of infestation and here, because the trees were kept well shaded and protected from the drying winds by a large guava and were well watered at all times during the dry season, there seemed to be no checking of the development of the black fly at any time.

However, while these trees showed some injury, i. e., a dropping of perhaps 5 to 10 per cent of their total number of leaves, they were far from being killed. Neither did the infestation of *woglumi* seriously interfere with the production of fruit on them. The infestation, however, rendered the trees extremely unsightly. These trees, like those in Plate II, figure 2, and Plate III, figure 2, put forth an abundance of young growth with the coming of the wet season (from the middle of April to the last of June), and seemed to be outgrowing the *woglumi* infestation.

In contrast with these two groups of limes is the young orange tree shown in Plate I. This is one of the few trees of this species that were readily accessible for daily observation. The degree of infestation in October, 1918, is shown in Plate I, A, and Pl. IV, fig. 1. By the end of November, 1918, the infestation was very severe, the underside of every leaf being a mass of eggs and individuals in all stages of development. On the younger leaves it was estimated from counts that there were between 3,500 and 4,000 eggs per leaf, and when these began hatching the undersides were black with larvæ just as if they had been dusted with soot. Due to this overcrowding on the part of the insects on the leaves there was unquestionably a heavy drain on the sap supply of the tree and when the dry season set in during the latter part of December, the tree began shedding its leaves, in spite of the fact that it was watered daily. The following is the apparent explanation of this defoliation: During the dry season

in the Canal Zone there is always a steady breeze blowing which naturally increases transpiration from the leaves. This increased transpiration, coupled with the drain on the sap supply due to the insects, caused the wilting and subsequent dropping of the leaves so that by April, 1919 (the end of the dry season) (Pl. I, B), fully 75 per cent of the total number of leaves were lost. This loss of leaves, however, seemed to be a benefit to the tree, for when a leaf wilted it checked the development of all stages of the black fly occurring on it and when it fell large numbers of the insects were killed, as is shown by experiments on the effects of drying on the emergence both of larvæ from eggs and of adults from pupæ. Likewise, the rate of reinfestation from April to September, 1919, has been very slow, due to the fact that practically all heavily-infested leaves were shed. But this tree is far from being dead, and with the coming of the wet season in the middle of April, it put forth an abundance of new growth, the greater part of which was free from *woglumi*, so that one not knowing its previous history would scarcely suspect that it had been one of the most heavily-infested trees found in the Canal Zone.

The observations on this tree were checked against those made on both orange and tangerine trees heavily infested with *A. woglumi* in the Las Sabanas region of Panama. Here the trees were unwatered, but the fact that they were of considerable size, close together, and protected by windbreaks, offsets this factor. The percentage of leaves lost was not as great as in the case of the tree at Ancon, due no doubt to a checking of the development of the black fly during the dry season so that the infestation at the end of the dry season was noticeably less than at the beginning. There was nothing here to indicate that either the quantity or quality of the fruit had been seriously reduced by the black fly.

In several instances in the outlying parts of the Las Sabanas region various kinds of citrus that were well cared for, but received water only at long intervals or not at all, were found to be in a badly wilted condition, but examination showed them to be entirely free from *woglumi*. Such trees, however, seemed able to resist the drought much better than infested ones and did not lose as large a percentage of leaves. On the other hand, trees in the same region and likewise uninfested but neglected in every way were found to be decidedly dwarfed in size and many were dead and dying. These same conditions were verified in the Canal Zone.

In the village of Taboga on the island of that name, lime trees growing under very adverse conditions and heavily infested showed some injury but not as much as might have been expected.

At Frijoles and Corozal dead and dying lime trees were found. At the first place neither scale insects nor the black fly were present,


THE BLACK FLY.

Young orange trees at Ancon, Canal Zone, kept under daily observation for over a year. *A*, Photographed in October, 1918; *B*, photographed in April, 1919, shortly after the beginning of the rainy season. Note the defoliation due to a heavy infestation of *Aleurocanthus woglumi*, and compare with Plate IV, figure 1.

FIG. 1.—INFESTED LIME LEAVES, SHOWING VARIOUS STAGES OF DEVELOPMENT OF INFESTATION.

These leaves were taken from trees shown in figure 2.

FIG. 2.—YOUNG LIME TREES MODERATELY INFESTED THAT WERE KEPT UNDER DAILY OBSERVATION FOR OVER A YEAR. PHOTOGRAPHED IN OCTOBER, 1918.

THE BLACK FLY.

FIG. I.—INFESTED LIME LEAVES TAKEN FROM TREES SHOWN IN FIGURE 2, IN MAY, 1919. COMPARE WITH PLATE II, FIGURE I.

FIG. 2.—THE SAME TREES SHOWN IN PLATE II, FIGURE 2, PHOTOGRAPHED IN APRIL, 1919, SHORTLY AFTER THE BEGINNING OF THE RAINY SEASON.

Note the vigorous growth.

THE BLACK FLY.

FIG. 1.—INFESTED ORANGE LEAVES FROM TREE SHOWN IN PLATE I. TAKEN IN OCTOBER, 1918.

In April, 1919, due to heavy shedding of infested leaves during the dry season, the tree was only lightly infested.

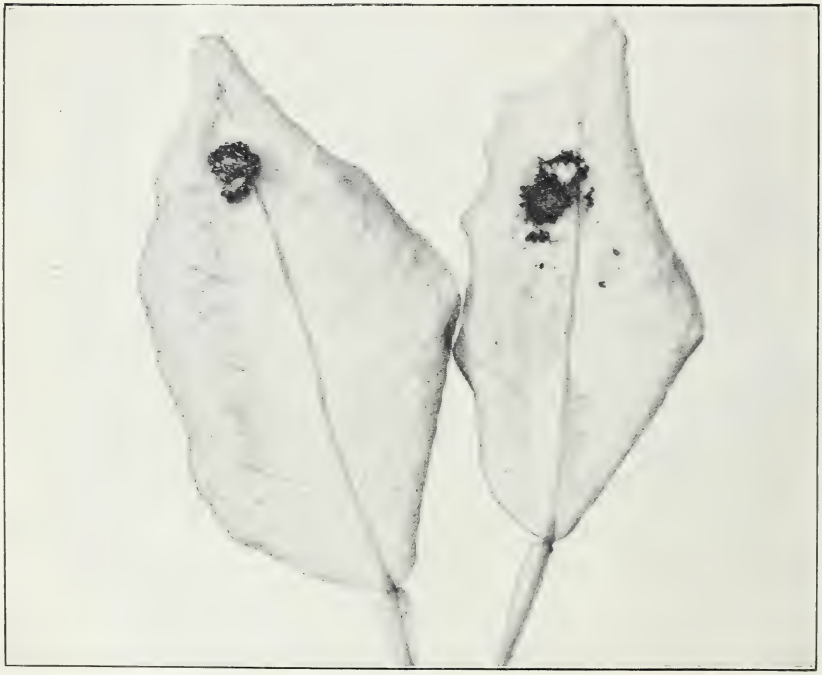


FIG. 2.—PUPA CASES OF CHRYSOPA SP., THE LARVÆ OF WHICH ARE PREDATORY ON ALL STAGES OF ALEUROCANTHUS WOGLUMI.

Note the masses of empty skins of the victims.

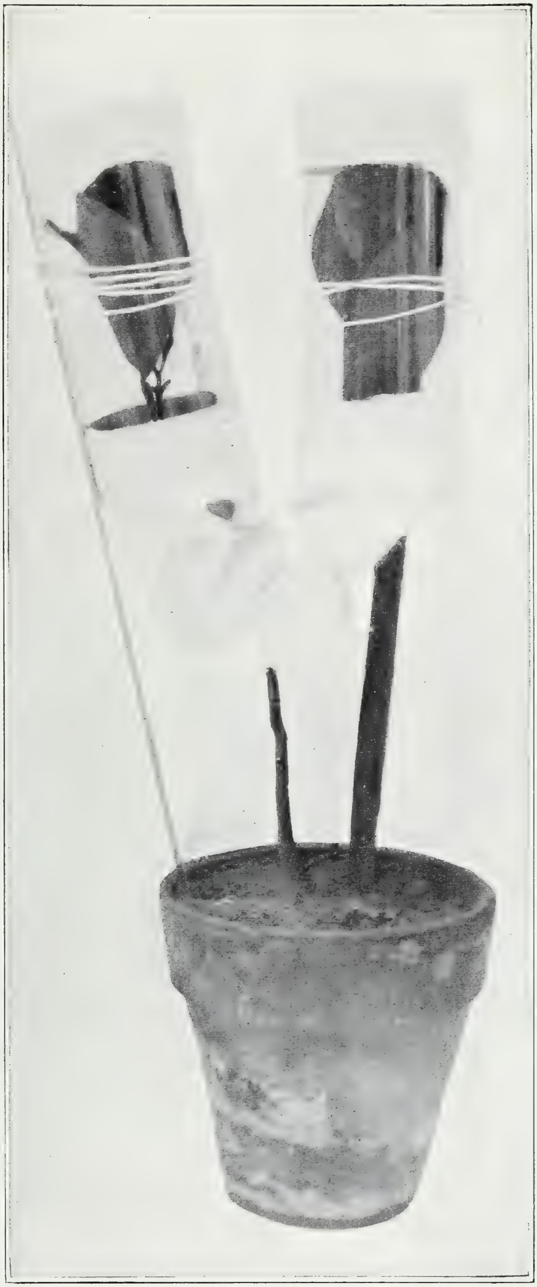
THE BLACK FLY.

THE BLACK FLY

Leaves from heavily infested lime trees coated with "sooty mold" growing on the honeydew excreted by the insect.

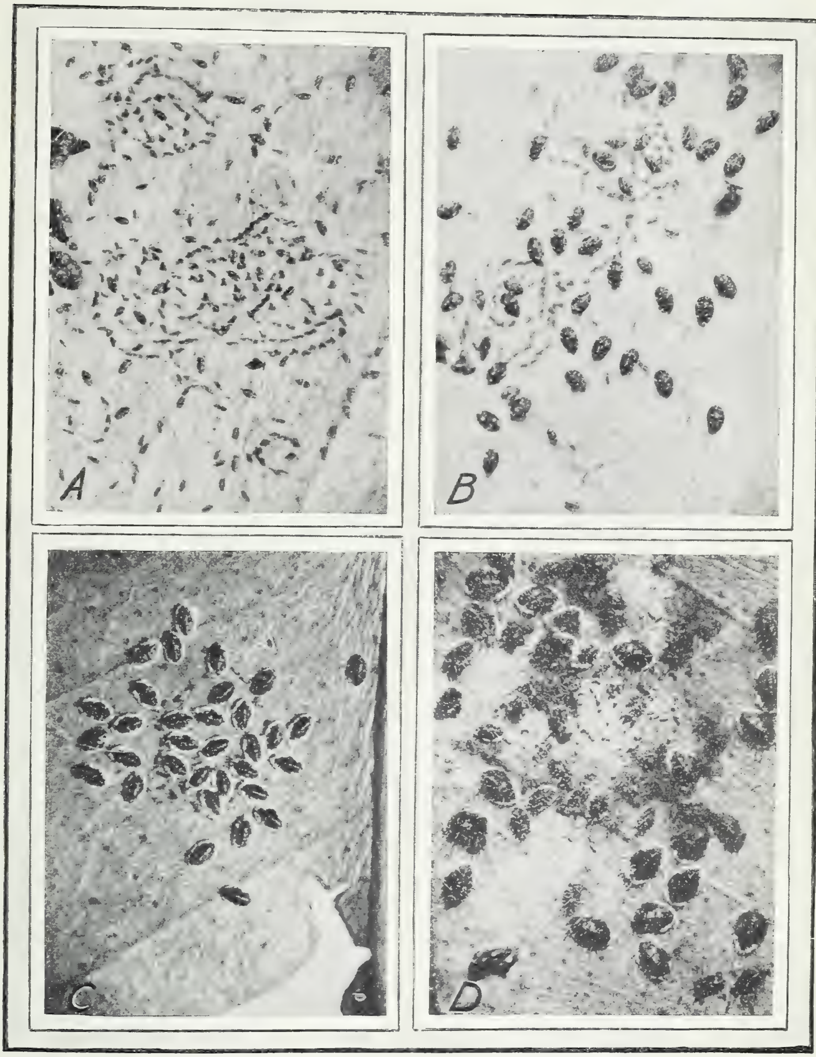
THE BLACK FLY.

The undersurface of the same shoot shown in Plate V.



THE BLACK FLY.

Celluloid cages in which adults were confined in order to obtain egg spirals for observation.




STAGES IN THE LIFE HISTORY OF THE BLACK FLY.

*A*, Eggs and first and second instar larvæ; *B*, eggs and third instar larvæ; *C*, male pupæ; *D*, female pupæ. All enlarged to the same scale (taken with 48 mm. lens).

but the injury seemed to be due to neglect and to the fungus (*Gloeosporium gloeosporoides*), which had gained entrance to the trees through pruning wounds. At Corozal the injury seemed to be due to heavy infestations of the purple scale (*Lepidosaphes beckii* Newm.), and of the West Indian red scale [*Pseudaonidia* (*Selenaspidus*) *articulatus* Morg.]. These dying lime trees were not heavily infested with *A. woglumi*.

In the authors' work at Ancon, Balboa, and Cristobal, it was found that when citrus trees (lime, orange, and grapefruit) were heavily infested with the two scales mentioned above, they were almost invariably only lightly infested with *A. woglumi* even though they were in close proximity to trees heavily infested with this insect. From the authors' experience then it would seem that the infestations of scale insects and the black fly go on independently of each other and it does not necessarily follow "that an infestation of the black fly is invariably accompanied by rapidly increasing scale infestations so that the life of an infested tree is necessarily short" (25). That this may take place is not denied, but that it has not taken place in the Canal Zone to date is the result of a year's observation in that region. It has also been observed that heavy infestations, especially of the West Indian red scale, serve as a decided inhibition to the development of the black fly, as will be pointed out under the life history of the insect. The writers find that the two scales mentioned do far more actual and noticeable damage than the black fly in that they actually kill infested areas on the leaves and cause infested twigs to die. In many instances the cultural conditions and neglect to which trees have been subjected are in themselves sufficient to injure them seriously even if no insect or fungous pests were involved and such factors coupled with a heavy infestation of the black fly doubtless will, in time, prove a handicap that these trees will be unable to overcome in spite of the fact that the climatological conditions of this region are extremely favorable to plant development.

Since in all the survey work conducted by the authors a tree was never found killed by the black fly, it is safe to conclude that much of its injury is "ornamental" and that the fact that it makes heavily infested trees decidedly unsightly has been largely responsible for the exaggerated statements regarding its destructiveness.

In conclusion the authors' work bears out the following statements of Morrison, who has seen the insect and its injury in the Canal Zone, Jamaica, and Cuba: "It may be said that the presence of this pest in numbers affects adversely the infested tree, and may in cases where other factors are also unfavorable be the final handicap which prevents the production of a crop of fruit or reduces it in size until it is unprofitable commercially to grow such a crop, or prevents the trees from making the amount of new growth each year which is necessary

to their proper development. There is nothing to indicate that, if it succeeded in entering the United States, it would prove to be an almost hopeless case * * * though it would without question prove to be a heavy additional load for citrus growers already burdened with numerous other injurious insects and diseases."

## LIFE HISTORY AND HABITS.

In this work certain difficulties due to the habits of the adults of *A. woglumi* had to be overcome. These habits made it impossible, in many instances, to secure much desired data by the direct method. The data desired were the number of eggs laid by a single female; whether unfertilized females lay only eggs that give rise to males; how soon after emergence copulation takes place; the length of life of the adults; and how soon after emergence egg-laying begins. The difficulty of finding out these facts by the direct method, namely, by taking individuals of known history and confining them with leaves in cages (Pl. VII) or in petri dishes, was due to the nervousness of the adults when they were disturbed or handled. Whether adults were confined singly or in numbers seemed to make little difference. Once they were disturbed and confined, they would worry themselves to death in their attempts to escape and instead of resting on the leaves of the plant to which they were confined they would wander up and down the sides of the cage. Often pupæ from which adults were ready to emerge were placed in petri dishes with fresh leaves, but almost invariably on emergence the adults, after becoming thoroughly colored, would begin wandering around the cage in their attempts to get away. In no case did adults obtained in this way live over four days. Therefore, another and less accurate method of observing the habits of the adults and obtaining spirals for life-history work had to be adopted. Large numbers of males and females were brought into the laboratory on the young shoots on which they were found resting in the field. Copulation was usually in progress and this insured obtaining normal fertilized eggs. These shoots were placed in water and as they wilted the males and females would leave them. Therefore, such shoots were set among young trees so that the adults could congregate on these. For a time this method was successful, but it often failed, apparently due to the fact that the females preferred to lay eggs on the wilted leaves rather than on those of the trees that were provided. This may have been due to the age of the leaves on the trees, but no such pronounced selection on the part of the females in the field has been observed. In the field, spirals which from their color and from actual observation were known to have just been laid were used. Those were chosen that occurred alone on the leaves, or if any other spirals happened to be laid on the same leaf, which was rarely the case,

these were removed. The chosen spirals were observed daily, or three times daily in many instances, until the life cycle was complete. Hence by close observations in the field and by a careful study of the habits of the insects in all stages in the laboratory, answers to most of the questions mentioned before, and which could not be determined by the direct method, have been obtained.

Two methods were used in obtaining the life history of this insect, namely, the group method and the individual method. Both had certain advantages and disadvantages. The group method consisted in taking an egg spiral laid on a known date, watching for the eggs to hatch, and then making observations on the individuals from one to three times daily until they had completed their life cycle. In this case, however, only the number of individuals that passed from one instar to another on a given date was recorded day by day. The individual method consisted in accurately plotting the egg spiral and the position of the larvæ after they had settled and giving each one a number to be retained by it throughout its development. The time when each molted was then recorded, thus giving a very accurate record of the development of each individual. The advantage of the group method is that it is a rapid one and shows readily by a glance at the chart how many individuals die in a given instar, the duration of a given molt, and the time of the maximum molting for a given molt. (See fig. 5.) From such a chart the life-history curve of the individuals of one lot of eggs can be plotted directly. The great objection to this method is that it does not give a clear-cut individual record, which is also desirable. The advantages and disadvantages of the individual records are just the inverse of the group record, but the chief objection in the work here was that this method was too slow and there was in many cases a waste of time due to the great mortality of *A. woglumi*, especially in the first instar, as will be shown later. The two kinds of records taken together make an ideal combination, as one can be used to interpret the other.

The following tables are representative of the two methods of recording the life history and show the range and variation under favorable (field) conditions and more or less unfavorable (laboratory) conditions. In the laboratory the small trees used were watered daily, but the humidity was often as much as 20 per cent lower indoors than out-of-doors, and there was generally a considerable breeze blowing through the room. Likewise the light in the room was dull and it seems that all the factors taken together retarded the individuals, especially in the pupal stage. But laboratory data give a clue to the ability of the species to adapt itself to its environment and likewise indicate what takes place in the dry season, especially in a region like Las Sabanas.

It is seen, therefore, that Ashby (3) is right fundamentally regarding the life history of the black fly. But he did not go far enough in his studies. The life history is not clear-cut, as one is led to believe from his brief work, and is greatly influenced by conditions. The total length of time from the egg to the adult as given by him and Cardin (11) may be much longer than they indicate. Some of the individuals do go through their development in as few as 55 days, but there is a great variation and the majority take a

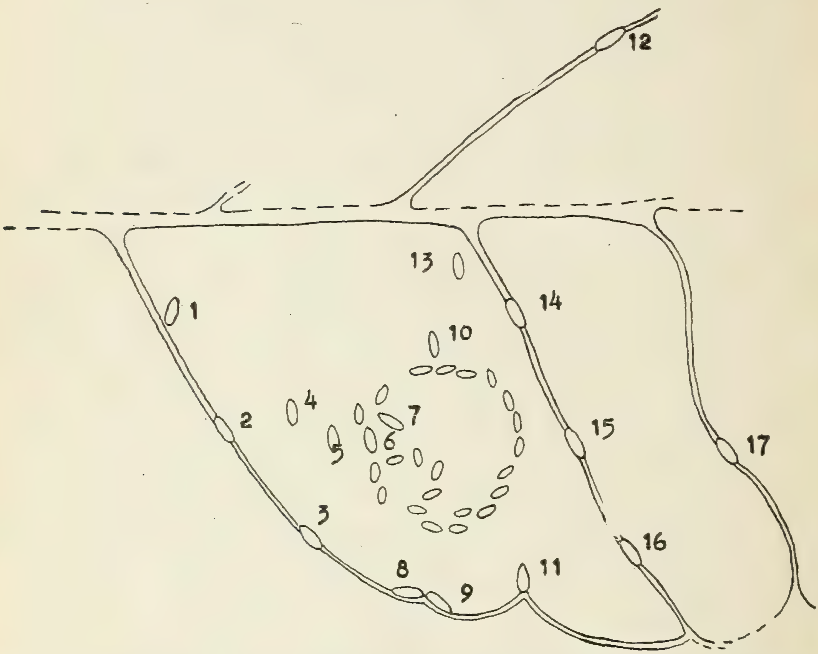



FIG. 5.—Diagrammatic chart showing method used in keeping record of individuals of *Aleurocanthus woglumi* in life-history work.

longer time, especially under unfavorable conditions. There is considerable variation in the length of time that individuals remain in each instar, the greatest variation being in the time that they remain in the pupal stage. This is true in a colony all of whose individuals hatched from the same egg spiral. There seems to be a constant dropping back of some individuals so that the group life history is drawn out.

The time for the complete development from egg to adult, as is shown by the tables, ranges from 55 (45 the minimum) to 113 (the maximum) days.

TABLE VI.—*Life history of Aleurocanthus woglumi.*

GROUP RECORD 2 (1918), INDOOR EXPERIMENT. HOST: LIME.

| Eggs laid. | No. | Hatched. | No. | First molt. | No. | Second molt. | No. | Third molt. | No. | Adults. | No. | Sex.[1] M.[1] | Sex.[1] F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 6[2] | 55 | Aug. 17 | 30 | Aug. 25 | 30 | Sept. 1 | 6 | Sept. 10 | 2 | Oct. 7 | 2 | .... | .... |
| | | Aug. 18 | 20 | Aug. 26[3] | 17 | Sept. 2 | 9 | Sept. 11 | 9 | Oct. 8 | 1 | .... | .... |
| | | Aug. 19 | 5 | .......... | .... | Sept. 3 | 17 | Sept. 12 | 6 | Oct. 11 | 1 | .... | .... |
| | | | | | | Sept. 4[4] | 2 | Sept. 13 | 5 | Oct. 12 | 1 | .... | .... |
| | | | | | | | | Sept. 14[5] | 2 | Oct. 15 | 1 | .... | .... |
| | | | | | | | | | | Oct. 23 | 1 | .... | .... |
| | | | | | | | | | | Oct. 24 | 1 | .... | .... |
| | | | | | | | | | | Oct. 31 | 1 | .... | .... |
| | | | | | | | | | | Nov. 1 | 2 | .... | .... |
| | | | | | | | | | | Nov. 5 | 1 | .... | .... |
| | | | | | | | | | | Nov. 12[6] | 1 | .... | .... |
| Total | 55 | .......... | 55 | .......... | 47 | .......... | 34 | .......... | 24 | .......... | 13 | 13 | .... |

GROUP RECORD 4 (1918), INDOOR EXPERIMENT. HOST: LIME.

| Eggs laid. | No. | Hatched. | No. | First molt. | No. | Second molt. | No. | Third molt. | No. | Adults. | No. | M. | F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 26 | 38 | Oct. 10 | 27 | Oct. 17[7] | 4 | Oct. 26 | 1 | Nov. 5 | 1 | Nov. 26 | 1 | .... | 1 |
| | | Oct. 14 | 1 | Oct. 18 | 1 | Oct. 27 | 1 | Nov. 6 | 1 | Dec. 2 | 1 | 1 | .... |
| | | Oct. 15[8] | 5 | Oct. 19 | 3 | Oct. 28 | 1 | Nov. 12 | 3 | Dec. 8 | 1 | 1 | .... |
| | | | | Oct. 20 | 1 | .......... | .... | Nov. 15[9] | 2 | Dec. 10 | 1 | .... | 1 |
| | | | | Oct. 21 | 3 | Oct. 30 | 1 | .......... | .... | Dec. 14[10] | 1 | .... | 1 |
| | | | | | | Oct. 31 | 1 | .......... | .... | .......... | .... | .... | .... |
| | | | | Oct. 22[11] | 2 | Nov. 1[12] | 3 | .......... | .... | .......... | .... | .... | .... |
| Total | 38 | .......... | 33 | .......... | 14 | .......... | 8 | .......... | 7 | .......... | 5 | 2 | 3 |

GROUP RECORD 32 (1919), OUT-OF-DOORS EXPERIMENT. HOST: LIME.

| Eggs laid. | No. | Hatched. | No. | First molt. | No. | Second molt. | No. | Third molt. | No. | Adults. | No. | M. | F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May 11 | 20 | May 24 | 11 | June 2 | 14 | June 7 | 6 | June 18 | 5 | July 5 | 4 | 4 | .... |
| | | May 25 | 3 | June 3 | 1 | June 8 | 0 | June 19 | 5 | July 6 | 2 | .... | 2 |
| | | May 27[13] | 4 | June 4[14] | 1 | June 9 | 6 | June 20 | 1 | July 9 | 1 | .... | 1 |
| | | | | | | June 10 | 2 | June 21 | 5 | July 10 | 3 | .... | 3 |
| | | | | | | June 11 | 1 | .......... | .... | July 11 | 3 | .... | 3 |
| | | | | | | June 12 | 1 | .......... | .... | July 12 | 3 | 2 | 1 |
| Total | 20 | .......... | 18 | .......... | 16 | .......... | 16 | .......... | 16 | .......... | 16 | 6 | 10 |

GROUP RECORD 36 (1919), OUT-OF-DOORS EXPERIMENT. HOST: ORANGE.

| Eggs laid. | No. | Hatched. | No. | First molt. | No. | Second molt. | No. | Third molt. | No. | Adults. | No. | M. | F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May 12 | 48 | May 24[15] | 11 | June 2 | 8 | June 7[16] | 2 | June 15 | 2 | July 4 | 2 | .... | 2 |
| | | May 25 | 13 | June 3 | 2 | June 8 | 0 | June 16 | 3 | July 5 | 3 | 2 | 1 |
| | | May 26 | 20 | June 4 | 1 | June 9 | 5 | June 17 | 1 | July 6 | 1 | .... | 1 |
| | | | | June 5[17] | 0 | June 10 | 1 | June 18 | 1 | July 7 | 1 | 1 | .... |
| | | | | June 6[17] | 2 | June 11 | 1 | June 19 | 2 | July 8 | 1 | .... | 1 |
| | | | | | | | | | | July 10 | 1 | 1 | .... |
| Total | 48 | .......... | 44 | .......... | 13 | .......... | 9 | .......... | 9 | .......... | 9 | 4 | 5 |

[1] All males.
[2] Laid by unfertilized female.
[3] Eight first larval instar individuals dropped off while molting.
[4] Four second larval instar individuals died in this stage. Nine fell off.
[5] Ten third larval instar individuals died in this stage.
[6] Leaf fell on Dec. 28, 1918, without further emergence from 9 pupæ that were left. Two fell off.
[7] Ten first larval instar individuals lost in molting.
[8] Three eggs failed to hatch and 2 first larval individuals were lost.
[9] One third larval instar individual died in this stage.
[10] Leaf fell Dec. 24, 1918, without emergence from 1 male and 1 female pupa.
[11] Nine first larval instar individuals died in this stage.
[12] Six second larval instar individuals died in this stage.
[13] Eggs all hatched; two first larval instar individuals fell off before settling down.
[14] Two first larval instar individuals fell off in molting.
[15] All eggs hatched; 4 first larval instar individuals fell off before settling down.
[16] See [17], 4 second larval instar individuals washed off.
[17] On June 5 and 6, 31 first larval instar individuals and 4 second larval instar individuals were washed off by heavy rains at molting time.

TABLE VI.—*Life history of Aleurocanthus woglumi*—Continued.

GROUP RECORD 42 (1919), OUT-OF-DOORS EXPERIMENT. HOST: ORANGE.

| Eggs laid. | No. | Hatched. | No. | First molt. | No. | Second molt. | No. | Third molt. | No. | Adults. | No. | Sex. M. | Sex. F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May 15 | 32 | May 27 | 6 | June 3 | 5 | June 10 | 1 | June 19 | 1 | July 12 | 3 | 3 | .... |
| | | May 28 | 0 | June 4 | 5 | June 11 | 1 | June 20 | 0 | July 14 | 1 | 1 | .... |
| | | May 29 | 3 | June 5 | 6 | June 12 | 2 | June 21 | 2 | July 15 | 1 | .... | 1 |
| | | May 30 | 0 | June 6 | 2 | June 13 | 8 | June 22 | 4 | July 16 | 3 | .... | 3 |
| | | May 31 | 10 | June 7 | 6 | June 14 | 2 | June 23 | 2 | July 17 | 1 | .... | 1 |
| | | June 1[18] | 12 | June 8[19] | 5 | June 15 | 3 | June 24–June 29 | 5 | July 18 | 1 | .... | 1 |
| | | | | | | June 16 | 6 | June 30 | 2 | July 21 | 1 | 1 | .... |
| | | | | | | June 17–June 18 | 0 | July 1 | 2 | July 22 | 1 | .... | 1 |
| | | | | | | June 19[20] | 1 | July 2–4 | 0 | July 23 | 1 | .... | 1 |
| | | | | | | | | July 5[21] | 1 | July 25[22] | 1 | 1 | .... |
| Total | 32 | .......... | 31 | .......... | 29 | .......... | 24 | .......... | 19 | .......... | 14 | 6 | 8 |

GROUP RECORD 47 (1919), INDOOR EXPERIMENT. HOST: LIME.

| Eggs laid. | No. | Hatched. | No. | First molt. | No. | Second molt. | No. | Third molt. | No. | Adults. | No. | Sex. M. | Sex. F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May 10 | 81 | May 21 | 4 | May 30 | 5 | June 5 | 3 | June 14 | 1 | July 11 | 1 | 1 | .... |
| | | May 22 | 17 | May 31 | 6 | June 6 | 5 | June 15 | 5 | July 14 | 1 | 1 | .... |
| | | May 23 | 28 | June 1 | 5 | June 7 | 4 | June 16 | 3 | July 17 | 3 | 2 | 1 |
| | | May 24 | 5 | June 2[23] | 6 | June 8 | 5 | June 17 | 2 | July 18 | 1 | .... | 1 |
| | | May 25[24] | 4 | June 3[23] | 12 | June 9 | 1 | June 18 | 2 | July 20 | 1 | .... | 1 |
| | | | | June 4 | 6 | June 10 | 5 | June 19 | 4 | July 25 | 1 | .... | 1 |
| | | | | June 5[25] | 5 | June 11 | 1 | June 20 | 0 | July 28 | 1 | .... | 1 |
| | | | | | | June 12 | 6 | June 21 | 1 | July 29 | 1 | .... | 1 |
| | | | | | | June 13[26] | 7 | June 22 | 7 | July 31 | 1 | .... | 1 |
| | | | | | | | | June 23 | 2 | Aug. 1 | 2 | .... | 2 |
| | | | | | | | | June 24 | 1 | Aug. 2 | 2 | 1 | 1 |
| | | | | | | | | June 25 | 2 | Aug. 4 | 2 | .... | 2 |
| | | | | | | | | June 26[27] | 3 | Aug. 10 | 1 | 1 | .... |
| | | | | | | | | | | Aug. 15 | 1 | .... | 1 |
| | | | | | | | | | | Aug. 18 | 1 | .... | 1 |
| | | | | | | | | | | Aug. 20 | 2 | 2 | .... |
| | | | | | | | | | | Aug. 22 | 1 | 1 | .... |
| | | | | | | | | | | Sept. 3 | 1 | 1 | .... |
| | | | | | | | | | | Sept. 19 | 1 | 1 | .... |
| | | | | | | | | | | Sept. 25 | 2 | .... | 2 |
| | | | | | | | | | | Sept. 28 | 1 | .... | 1 |
| | | | | | | | | | | Sept. 30[28] | 2 | .... | 2 |
| Total | 81 | .......... | 58 | .......... | 45 | .......... | 37 | .......... | 33 | .......... | 30 | 11 | 19 |

[18] All eggs hatched; 1 first larval instar individual lost in settling down.
[19] Two first larval instar individuals died in that stage.
[20] Five second larval instar individuals died in that stage.
[21] Five third larval instar individuals died in that stage.
[22] Tree sprayed with nicotine oleate on July 25 and 5 pupæ, 3 females, and 2 males were killed.
[23] Three second larval instar individuals removed for study. These had just molted.
[24] Fifteen eggs failed to hatch. These were not parasitized. Eight first larval instar individuals were lost before settling down.
[25] Three first larval instar individuals (still alive) removed for study. Ten first larval instar individuals died in this stage.
[26] Two second larval instar individuals died in this stage.
[27] Four third larval instar individuals died in this stage.
[28] Three pupæ still unreported on.

TABLE VI.—*Life history of Aleurocanthus woglumi*—Continued.

INDIVIDUAL RECORD 1 (1919), INDOORS. HOST: LIME.

| Egg laid. | Number. | Hatched. | Number. | Individual number. | First molt. | Time. | Second molt. | Time. | Third molt. | Time. | Sex. | Adult. | Time. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Days. | | Days. | | Days. | | | Days. |
| June 7 | 22 | June 20, a. m.[1] | 18 | 1 | Died in molting, June 29. | | Fell off, July 4 | | | | | | |
| | | | | 2 | June 28, p. m. | 8 | do | | | | | | |
| | | | | 3 | June 27, a. m. | 7 | do | | | | | | |
| | | | | 4 | do | 7 | do | | | | | | |
| | | | | 5 | do | 7 | do | | | | | | |
| | | | | 6 | June 29, p. m. | 9 | do | | | | | | |
| | | | | 7 | June 27, p. m. | 7½ | do | | | | | | |
| | | | | 8 | June 27, a. m. | 7 | do | | | | | | |
| | | | | 9 | | | Dead, July 7 | | | | | | |
| | | | | 10 | | | Fell off, July 5 | | | | | | |
| | | | | 11 | June 27, a. m. | 7 | Fell off, July 4 | | | | | | |
| | | | | 12 | June 28, p. m. | 8½ | July 5, p. m. | 7 | July 15, a. m. | 9½ | ([2]) | Aug. 8, p. m. | 24 |
| | | | | 13 | June 27, a. m. | 7 | Fell off, July 4 | | | | | | |
| | | | | 14 | June 27, p. m. | 7½ | do | | | | | | |
| | | | | 15 | June 27, a. m. | 7 | July 7, p. m. | 9 | July 17, a. m. | 9½ | ([2]) | Aug. 20, p. m. | 34 |
| | | | | 16 | June 28, p. m. | 8½ | Fell off, July 4 | | | | | | |
| | | | | 17 | June 28, a. m. | 8 | July 5, a. m. | 7 | July 14, a. m. | 9 | ([2]) | Aug. 7, p. m. | 23½ |
| | | | | 18 | Fell off, June 26 | | | | | | | | |

INDIVIDUAL RECORD 2 (1919), INDOORS. HOST: LIME.

| Egg laid. | Number. | Hatched. | Number. | Individual number. | First molt. | Time. | Second molt. | Time. | Third molt. | Time. | Sex. | Adult. | Time. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| June 7[3] | 28 | June 19 | (?) | 1 | July 1, a. m. | 12 | Died | | | | | | |
| | | June 20 | | 2 | June 27, p. m. | 7 | July 5, a. m. | 7½ | July 16, p. m. | 11½ | ([2]) | Aug. 23, a. m. | 37½ |
| | | do | | 3 | June 29, a. m. | 9 | July 6, p. m. | 7½ | do | 10½ | ([4]) | | |
| | | June 19 | (?) | 4 | do | 10 | Died | | | | | | |
| | | do | (?) | 5 | June 28, p. m. | 9 | do | | | | | | |
| | | do | (?) | 6 | June 30, p. m. | 11 | July 7, p. m. | 7 | July 16, p. m. | 9 | ([2]) | Aug. 18 | 33 |
| | | June 20 | | 7 | July 1, a. m. | 11 | July 8, a. m. | 7 | do | 8½ | ([4]) | Sept. 30, a. m. | 75½ |
| | | do | | 8 | June 30, a. m. | 10 | July 9, p. m. | 9½ | July 27, p. m. | 18 | ([4]) | | |
| | | June 19 | (?) | 9 | June 28, a. m. | 9 | July 5, p. m. | 7½ | July 16, p. m. | 11 | ([4]) | Aug. 18 | 33 |
| | | June 20 | | 10 | Died | | | | | | | | |
| | | do | | 11 | July 4, a. m. | 14 | July 15, a. m. | 11 | Died | | | | |
| | | do | | 12 | June 30, a. m. | 10 | July 7, p. m. | 7½ | July 16, p. m. | 9 | ([4]) | Aug. 16, a. m. | 31 |

[1] One egg unhatched; three first larval instar individuals lost before settling down.
[2] Female.
[3] Two first larval instar individuals fell off before settling down.
[4] Male.

TABLE VI.—*Life history of Aleurocanthus woglumi*—Continued.

INDIVIDUAL RECORD 2 (1919), INDOORS. HOST: LIME—Continued.

| Egg laid. | Number. | Hatched. | Number. | Individual number. | First molt. | Time. | Second molt. | Time. | Third molt. | Time. | Sex. | Adult. | Time. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Days.* | | *Days.* | | *Days.* | | | *Days.* |
| June 7 | 28 | June 20 | | 13 | June 27, a. m. | 7 | July 5, p. m. | 8 | July 14, a. m. | 9 | ([4]) | Sept. 27, a. m. | 74½ |
| | | do | | 14 | Died | | | | | | | | |
| | | do | | 15 | June 27, p. m. | 7 | Died | | | | | | |
| | | do | | 16 | Gone, July 2 | | | | | | | | |
| | | do | | 17 | Gone, June 28 | | | | | | | | |
| | | do | | 18 | June 29, a. m. | 9 | July 6, a. m. | 7 | July 14, a. m. | 8 | ([4]) | Sept. 28, a. m. | 76 |
| | | do | | 19 | June 30, a. m. | 10 | July 8, a. m. | 8 | July 17, p. m. | 9½ | ([4]) | | |
| | | do | | 20 | Died | | | | | | | | |
| | | do | | 21 | June 29, a. m. | 9 | July 7, p. m. | 8½ | July 16, p. m. | 9 | ([4]) | | |
| | | do | | 22 | July 6, p. m. | 15 | Died | | | | | | |
| | | do | | 23 | June 29, a. m. | 9 | July 6, a. m. | 7 | July 15, a. m. | 9 | ([4]) | | |
| | | do | | 24 | June 28, a. m. | 8 | July 5, a. m. | 7 | July 14, a. m. | 9 | ([4]) | Aug. 11, p. m. | 29½ |
| | | do | | 25 | July 4, a. m. | 11 | July 15, a. m. | 11 | July 30, a. m. | 15 | ([4]) | Sept. 13, a. m. | 46 |
| | | do | | 26 | Gone, June 26 | | | | | | | | |

INDIVIDUAL RECORD 3 (1919), OUT-OF-DOORS. HOST: LIME.

| Egg laid. | Number. | Hatched. | Number. | Individual number. | First molt. | Time. | Second molt. | Time. | Third molt. | Time. | Sex. | Adult. | Time. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| June 17 | 15 | June 30 | 15 | 1 | July 11 | 11 | July 18, a. m. | 7 | July 28, a. m. | 10 | ([2]) | Aug. 19, p. m. | 22½ |
| | | | | 2 | Fell off, July 2 | | | | | | | | |
| | | | | 3 | July 9, p.m. | 9 | July 17, p. m. | 8 | July 27, a. m. | 9½ | ([2]) | Aug. 21, a. m. | 25 |
| | | | | 4 | July 8, p.m. | 8 | Fell off, July 8 | | | | | | |
| | | | | 5 | July 10, a.m. | 10 | July 18, p. m. | 8½ | July 27, a. m. | 8½ | ([2]) | Aug. 20, a. m. | 24 |
| | | | | 6 | July 9, p.m. | 9 | July 16, p. m. | 7 | July 24, a. m. | 7½ | ([4]) | Aug. 15, a. m. | 22 |
| | | | | 7 | do | 9 | July 18, p. m. | 8 | July 26, a. m. | 7½ | ([4]) | Aug. 24, a. m. | 29 |
| | | | | 8 | July 8, p.m. | 8 | July 16, a. m. | 7½ | July 24, a. m. | 8 | ([4]) | Aug. 15, a. m. | 22 |
| | | | | 9 | July 9, p.m. | 9 | Fell off, July 9 | | | | | | |
| | | | | 10 | July 8, p. m. | 8 | do | | | | | | |
| | | | | 11 | do | 8 | July 16, a. m. | 8 | July 24, a. m. | 8 | ([4]) | Aug. 16, a. m. | 23 |
| | | | | 12 | do | 8 | do | 8 | July 26, a. m. | 10 | ([2]) | Aug. 18, a. m. | 23 |
| | | | | 13 | Fell off, July 2 | | | | | | | | |
| | | | | 14 | July 11, p.m. | 11 | July 18, p. m. | 7 | July 26, a. m. | 8 | ([4]) | Aug. 16, a. m. | 23 |
| | | | | 15 | July 15, p.m. | 15 | Fell off, July 15 | | | | | | |

[2] Female.

[4] Male.

## EGGS.

The eggs (Pl. VIII, A, B) are normally laid in spiral form, when the adults are undisturbed, but there is a great irregularity in the shape of these "masses." In fact it is doubtful if more than 50 per cent of the eggs are laid in this form. Egg laying has been observed as short a time as 18 hours after the emergence of the adults (young tree and petri dish experiments in the laboratory) and as long a time as four (or more) days in individuals of unknown previous history brought into the laboratory on young citrus shoots for observation.

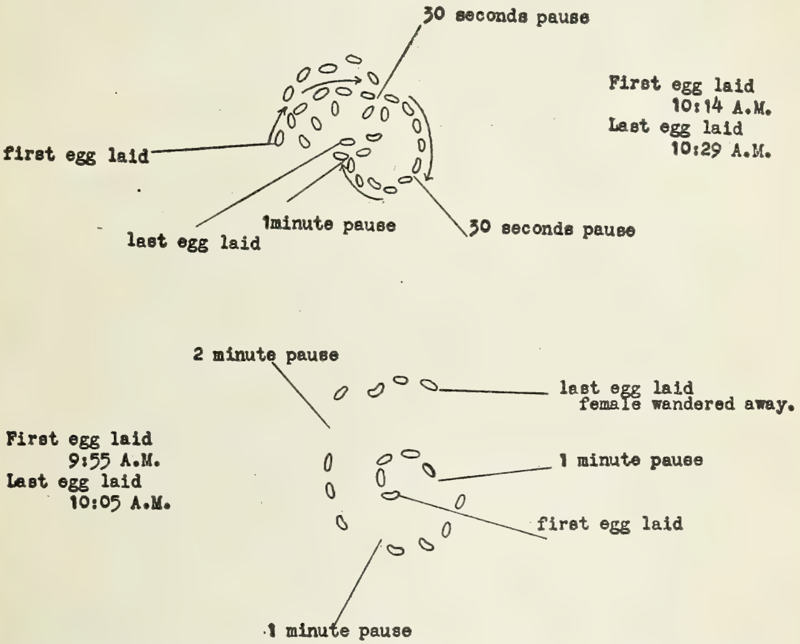



FIG. 6.—Diagrammatic drawings showing the procedure in oviposition of *Aleurocanthus woglumi.*

In laying eggs (fig. 6) the female usually starts at what becomes the center of the spiral (although the inverse of this has been observed) and facing outward begins a series of nervous vibrations and contractions. After from one to four such contractions and a rocking backward and forward she suddenly thrusts the end of her abdomen against the leaf and lays an egg, there being a noticeable contraction of the abdomen as the egg is expelled. During this oviposition the costal margins of the forewings rest against the surface of the leaf and serve to steady the female. The entire time for the deposition of a single egg including the shaking movement is usually from 15 to 30 seconds but sometimes takes as long as one or two minutes. After laying an egg the female moves forward a little, one-half the length of her body or more, and repeats the operation. When she has laid from 3 to 5

eggs, there is a rest of from 30 seconds to several minutes before oviposition is resumed and the female sometimes wanders around with wings fluttering, especially when observed. Since the distance which the female moves forward is variable and since she may be disturbed by other individuals on the leaf or by obstacles such as pupa cases or scale insects, the egg mass is often far from being a spiral. The figures show two masses. Molino and Dietz have observed 15 and 17 eggs laid in 15 minutes and likewise have seen as few as 3 eggs laid in 10 minutes.

In the field it has been observed that on bright sunshiny days the eggs are laid in the morning before noon, or in the late afternoon, times at which the relative humidity is highest. On cloudy days, when the relative humidity is fairly constant, egg laying may take place at any time during the day.

Normally, the eggs are laid on the undersides of the leaves, the females being negatively phototropic at the time of oviposition as is shown by the fact that when leaves on which females are laying eggs are turned over oviposition invariably soon ceases. In many cases a female will lay eggs within a few millimeters of the pupa case from which she has emerged. Likewise females seem to show little judgment as to where they lay eggs, this often resulting in decided overcrowding of young growth with eggs and the subsequent death of large numbers of developing individuals. Attention has been called to this under the heading "Spread of the insect," page 12. On a young orange on September 9, 1918, 50 spirals were counted on a single leaf and the following numbers were counted: 500 eggs in an area 10 by 30 mm. and 800 eggs in an area 20 by 25 mm. On September 30 there were at least 3,500 eggs on each leaf.

Some writers have called attention to the fact that eggs are laid on the fruit, and Morrison succeeded in getting a female in captivity to lay a normal spiral on a lemon fruit. Numerous inspections of lime, orange, and tangerine fruits on well-infested trees have failed to show that oviposition on the fruit in the field is a normal thing, for no stages of the black fly except occasional adults have ever been found on such fruit. Out of ten attempts, using 750 mixed adults brought in on young growth where they had clustered and confining them on half-ripe lime fruits, only one spiral of 19 eggs was obtained whereas a number of freshly laid spirals were found even on wilted leaves. Hence, it may be assumed that only on certain occasions and under certain conditions will eggs be found on the fruit of infested trees. This will probably be when the fruit is well shaded and the tree very heavily infested.

The number of eggs in a spiral or "mass" is as subject to variation as is the shape of the "masses" themselves and varies from 7 to 81, these being the extremes. Out of 118 spirals consisting of 3,798 eggs

the average was 32.19 eggs per spiral. However, the number of eggs laid in the laboratory on young shoots brought in from the field on which the adults had gathered was 26 per spiral, as against 36 for eggs laid on the leaves out of doors under natural conditions. Furthermore, out of 50 spirals laid in the laboratory only 8 had above 30 eggs and only 3 above 40, whereas out of the same number of spirals laid in the field 28 had above 30 eggs and 20 above 40. Hence, the normal number of eggs per spiral is between 35 and 50. Since different females have been observed to lay eggs as soon as 18 hours after emergence from the pupa case and as long as 4 days after emergence, there is but one conclusion, namely, that more than one spiral or mass of eggs is laid and that a single female may lay considerably over 100 eggs in her lifetime. If this were not the case, in view of the high mortality, especially in the early stages of development, it is doubtful if *Aleurocanthus woglumi* would be a pest of even secondary importance.

The individual egg is canoe shaped with its ends rounded. It is attached to the leaf by a short pedicel situated near its posterior end. When first laid the eggs are creamy white with what appears to be a reticulation of the surface, but in 36 to 48 hours they become brown in color, the reticulate appearance disappears, and they become blackish between the eighth and tenth days. In from 11 to 20 days the eggs hatch, the larvæ crawling forth through a slit along the median dorsal surface of the egg, the brown eggshell remaining plump and often very confusing as the slit seems to close again. Drying out of the leaves on which the eggs are laid seems to kill them, until one or two days before they are ready to hatch, as is shown later.

### FIRST LARVAL INSTAR.

The larva that emerges from the egg is rather elongate ovate in shape, whitish in color, with reddish eye spots, short antennæ, and rather short legs. It crawls around sluggishly for from two to four hours and then settles down, the farthest distance crawled, out of 580 individuals, being $1\frac{1}{2}$ inches from the center of the egg spiral. But fully 80 per cent of the larvæ never crawl more than one-half inch away from the spiral from which they emerge. On settling down the larva describes an arc of from 75 to 120 degrees, evidently to help in inserting its thread-like rostral setæ into the tissues of the leaf. This movement seldom lasts more than 20 minutes. Two hours after emergence from the egg the larvæ are dusky all over, with the exception of the margins, and within four hours they are fully colored, i. e., blackish, and more broadly ovate than on emergence. There is a tendency for them to flatten out. There is a pronounced median ridge, on each side of which, anteriorly and posteriorly, are four long dorsal spines and numerous shorter ones. Larvæ that have settled once have been observed to change their

position and go through the same rotating movement on settling down again. On leaves bearing large numbers of spirals or on small leaves, as in the case of orange jessamine (*Chalcas exotica*), the larvæ seem to show a tendency to settle down along the smaller veins of the leaf and parallel to them, but this position is lost, due to the rotation that takes place in the later larval instars just after molting.

The duration of the first larval instar ranges from 7 to 16 days, at which time the first molt takes place. In a great many cases, especially out of doors, larvæ that fail to molt before the sixteenth day fail to mature. The mortality in this instar, as is shown in both laboratory and field life-history work, is exceptionally high. Out of 580 individuals that entered this stage of development 190, or about 32 per cent, died.

### SECOND LARVAL INSTAR.

As the insect molts from the first to the second larval instar (Pl. VIII, A), a whitened margin along the sides of the insect can be seen as much as two days before the actual molt takes place. The individual has a decidedly distended appearance, and there is a slight constriction (almost unnoticeable in the first molt) on the side of the body apparently at the junction of the thorax and abdomen. Just before molting there is also a decided bulging along the line of the thorax and abdomen forming a transverse ridge. The insect seems to burst the anterior latero-ventral margin of its skin by pushing forward, and flows forth much like a drop of cream-colored viscous liquid. It begins at once to flatten out, being more ovate in shape than in the previous instar and quite disklike. This flattening out causes the skin to tear farther and farther back until at last the insect is free, with the skin attached to the dorsal spines. At this time the insect, both to free itself from its cast skin and to insert its rostral setæ, goes through some rather violent movements. It begins to rotate, describing an arc of from 45 to 180 degrees, and at the end of this movement it may raise the posterior portion of the body until it is almost over the anterior portion, so that as viewed from the side the insect would have a crescentic appearance. The insect may stay in this position as long as 5 minutes. Then again the posterior end of the body may be raised only slightly, and this movement be alternated with a "cupping up" movement, the insect assuming the shape of a person's hand when it grasps a pen. Or again at the end of each rotation the insect may merely rest for from 30 to 70 seconds. The time for normal procedure seems to be: Time to cast skin, 7 to 10 minutes; rotation with miscellaneous movements, 15 to 30 minutes. The entire time of molting, therefore, is about 40 minutes for the first molt. Several times it has been observed that insects started to molt and did not complete the operation until 24 hours later.

The early second larval instar individual is whitish in color, more ovate than in the preceding instar, and more or less flattened, with the eye spots and vasiform orifice quite prominent. Within three to four hours after molting the second larval instar becomes fully colored, i. e., dull black with the exception of a large, more or less circular spot on the anterior part of the dorsum, which remains a dull green. The insect is also decidedly more convex than in the preceding instar and the spines are more numerous and more prominent. The cast skin usually, though not always, remains attached to the long dorsal spines and rests near the middle of the dorsum of the second larval instar individual.

The duration of this instar ranges from 5 to 30 days in laboratory individuals, though the maximum time that has been observed out of doors is 21 days. The large majority of individuals molt between the eighth and thirteenth days.

Just before the second molt a color change takes place, which is noticeable from 18 to 30 hours before the skin is shed. This may be due to the distention of the individual at this time. Instead of a circular greenish area on the anterior dorsum one finds a crescentic black area anteriorly and a horseshoe-shaped area posteriorly and the green area more or less cruciform. The margin of the insect is whitish, just as it is in the premolting period of the first larval instar.

In life-history studies conducted by the writers, out of 390 individuals that entered this stage, 84, or about 21.5 per cent, died.

### THIRD LARVAL INSTAR.

The procedure in the second molt is the same as in the first, although the various stages in this process are more rapid and of shorter duration; the duration of the entire operation from the splitting of the skin to the complete cessation of the rotating and "cupping up" movements is from 15 to 20 minutes. The movements, though more easily observed than in the first molt, do not seem to be nearly as violent.

The time required for individuals to become fully colored, i. e., shiny black, is from one and one-half to two hours. The only portion of the body that does not become black is a more or less hemispherical dull green spot on the anterior part of the dorsum, situated over the greater part of the thorax and the anterior part of the abdomen. The spines are more numerous and stouter than in the second larval instar and the cast skin of the preceding stage (and often stages) remains attached to or entangled in the spines of the middle part of the dorsum. The convexity of the individuals becomes pronounced and the insect is distinctly ovate in outline.

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In this instar (Pl. VIII, B) sexes can be distinguished with certainty for the first time in the developmental stages, the males being at least one-third smaller than the females. The only complication in distinguishing the sexes seems to be between males and undersized females, although the latter are somewhat larger than the former.

The duration of the third larval instar is from 6 to 20 days, although out of doors the majority of individuals molt a third time between the eighth and fourteenth days after the second molt.

No color change has been observed in the third larval instar individuals preceding the third molt except that the dorsal hemispherical

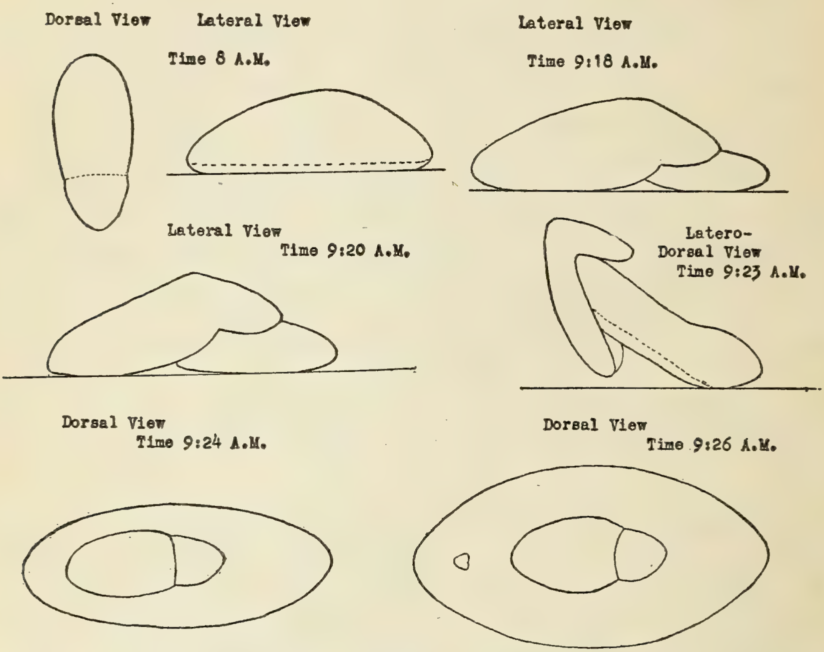



FIG. 7.—Diagrammatic drawings of the molting of *Aleurocanthus woglumi:* Third molt.

spot often becomes a lighter green and the whitish margin becomes very pronounced from one to four hours preceding the actual molting of the individual. Careful study of this has been made and appears to be due to the distention of the insect which permits the individual beneath to show through.

Of the individuals with which the writers worked, 38 out of 306, or almost 12.5 per cent, died.

### FOURTH INSTAR OR PUPA.

The third molt takes place very rapidly, the entire process being completed in 15 minutes. (See fig. 7.) The individuals are pale cream-colored, flat, and the marginal teeth are not visible immediately

after molting, but are pushed forth within the first 10 minutes. The individuals are flat at first and at the end of 15 minutes they become distended, with the numerous spines standing out conspicuously. The time for complete coloration, i. e., until the shiny black color so characteristic of this stage is reached, is from one to one and one-half hours.

The shape is distinctly ovate in outline, the anterior being the smaller end. The insect is decidedly convex, with a prominent ridge, and is covered with numerous long, stout, conspicuous spines.

The sexes are readily distinguished, the female pupæ being almost twice the size of the males. Furthermore, a white wax is secreted around the margins of the body, the males usually secreting noticeably more than the females.

The duration of the pupal period is very irregular and ranges from 16 to 80 days. Out of doors the maximum time that has been recorded is 48 days.

The mortality in this stage is not as great as in the preceding stages, only 28 out of 268 individuals, or little more than 10 per cent, dying.

In all the larval instars and in the pupal as well, shortly after the molting, it has been repeatedly noted that drops of a clear, more or less viscous fluid appear at the ends of practically all the spines. No openings have been noted at the ends of these spines after the insects have become fully colored, and they may only function for a short time and close, though this would seem to be a rather unusual condition. In some of the members of the genus Aleurocanthus the spines are distinctly open and in the genus Siphoninus the ilquid has been seen actually flowing from these openings.

In the larval and pupal stages varying amounts of honeydew are excreted through the vasiform orifice, some colonies of individuals secreting more than others. The amount of honeydew excreted depends upon the rate at which the insects are feeding. The honeydew falls on the leaves below the infested ones and soon sooty molds, fungi of the genus Meliola, begin growing on it. The heavy growth of the sooty molds on upper surfaces of the leaves, coupled with an abundance of *A. woglumi* individuals in various stages of development on the under surfaces, doubtless seriously interferes with the normal functioning of the leaves. (See Pls. V and VI.) Further, this double infestation may be so severe as to render leaves practically worthless to a tree and thus seriously interfere with its vigor. But infestations of *A. woglumi* are not necessarily accompanied by heavy growths of sooty mold, and the writers have found trees practically free from this insect and yet covered with heavy growths of these molds. In such instances the trees were usually badly infested with

nondiaspine scale insects or plant-lice which seem to excrete far more honeydew than does the black fly.

### FIFTH INSTAR, ADULT OR IMAGO.

When the adult (Pl. IX) is ready to emerge from the pupa case a T-shaped split appears at its anterior portion, the stem of which arises at the middle of the anterior margin and extends caudad along the median dorsal line to the junction of the thorax and abdomen. The arms of this T-shaped split extend to the right and left along the suture separating the thorax and abdomen. This split is visible from one-half hour to an hour before the adult begins to push forth. In emerging the adults push against this split, causing it to spread wider and wider open, and by a wriggling and up-and-down movement, interspersed with numerous rests to allow for some hardening of the various parts of the body, they finally succeed in escaping. Often they fall out in spite of desperate efforts to cling to the leaf and drop to the ground, where many probably die or fall victims to such insects as the ants. The time taken for normal emergence is from 14 minutes to one-half hour, though under dry conditions it may be as long as an hour and a half, or the insect may die without being able to escape.

The adults after freeing themselves from the pupa case usually rest beside it until various parts of their body become hardened, the only movements being more or less nervous ones, such as twitchings of the legs or wings to speed this process along.

When the adults first emerge the greater part of the body, i. e., the head, thorax, and abdomen, are a bright brick-red in color, with the front of the head (the vertex) pale yellow, the antennæ and legs whitish, and the eyes a deep red or reddish brown. The wings begin to fill out and are full size in from 18 to 30 minutes after the insect has emerged. In cases where the adults have trouble in freeing themselves from their pupa cases, the wings begin filling out, nevertheless, and thus may become crippled. After about one hour, the head, thorax, wings (with the exception of the colorless or whitish areas), and legs are quite dusky, but the sutures on the thorax and the entire abdomen remain a brick-red in color and the antennæ more or less whitish tinged with pale yellow. The eyes become a deep reddish brown. Within 6 to 12 hours the adults are fully colored, the color being merely an intensification of that previously set forth, the sutures of the thorax becoming smoky.

Within 24 hours after emergence, the insects become covered with a heavy pulverulence so that they have a general slaty blue appearance, with the colorless spots on the wings, when these are at rest, forming what appears to be a white band across the middle of the dorsum.

THE BLACK FLY.

Adults clustered on a young lime shoot. Natural size.

In the field the males are readily distinguished from the females by their noticeably smaller size and on closer observation by the difference in the structure of the end of the abdomen (see "Technical description," p. 41).

Humidity seems to be a very important factor in the time that emergence of adults from the pupa cases takes place, the maximum emergence in the field occurring in the early morning between 6 and 9 o'clock and dwindling down toward noon. Considerable emergence may take place in the late afternoon, following a rain, or at any time on cloudy, humid days.

After the bodies of the adults become hardened, the adults may rest by the pupa cases for anywhere from 3 hours to 5½ days in laboratory experiments. In the field the longest time observed was 1 day. Females often lay eggs within an inch or less of the pupa cases from which they have emerged, especially on lightly infested leaves. When they have left their original postion, after the hardening of the body, it seems to be an instinct of both sexes to congregate on the young growth of an infested tree probably both to obtain food and to insure fertilization of the females. Since it has been observed that females will lay eggs within a short distance from the pupa cases from which they have emerged it is probable that in the miscellaneous gatherings of adults on the young shoots three kinds of females are present: Those that have laid no eggs; those that have laid part of their eggs; and those that have laid all of their eggs.

Numerous counts of the number of males and females on the young growth of heavily and moderately infested trees were made in order to determine the ratio of the sexes present. On the heavily infested trees the number of males and females was usually equal. At times, however, the females would outnumber the males as much as 8 to 3. On the moderately infested trees there was a wide difference in the ratio of the sexes present, the proportions ranging from 5 males to 1 female to 7 females to 1 male. For the most part the females were more abundant. In counts made of the ratio of the sexes present in the pupal stage out of 25 colonies selected at random from moderately infested trees, 230 were females and 159 were males. On miscellaneous orange leaves, heavily infested, 450 were females and 471 were males. Out of 20 life-history spirals, 91 pupæ were males and 152 were females. This would tend to show that the females were more numerous than the males, and that the wide range in the numbers of each sex present at different times is probably due to the variation in the duration of the pupal stage even in the same colony.

Mating has been observed both in the field and in the laboratory. In the field it may take place at any time of the day, but seems to be more frequent in the late afternoon than at other times, due to the constantly increasing number of adults that gather on the young

growth throughout the day. The following is the procedure as observed in the laboratory on July 12, 1919: At 2.30 p. m. a number of young shoots on which a large number of adult males and females had gathered were brought in. The females were in the majority, there being about 5 females to every 2 males. These were carefully observed from 2.30 until 5 p. m. and copulation between at least 20 males and females (40 individuals) was witnessed. The males were found to rest beside the females with their bodies parallel to those of the females. Occasionally two males were found one on either side of a female. At intervals a certain nervous fluttering of the wings of the males was seen. This was carefully watched.

Beginning with a male resting beside a female, both acting normally, the following observation was made: The males would rest quietly beside the females for from three to five minutes. Then they would begin fluttering their forewings slowly and rhythmically at first. This fluttering of the wings continued with increasing intensity until it was very violent and consisted of very short rapid jerks, the forewings extending forward over the thorax and head of the insect at an angle of 120 degrees. Sometimes they stood straight up at an angle of 90 degrees to the body. The hindwings sometimes, though not always, were held rather close to the body and never more than an angle of 15 degrees away from it. In the height of this very rapid wing vibration there was a sudden pause with the wings extended forward. Then with an exceedingly rapid and sudden jerk the male thrust his abdomen under the normally resting wings of the female and the connection was made, apparently by the female being ready to receive the male and by moving the end of her abdomen into the proper position simultaneously with the male. The trembling movement lasted from 25 to 45 seconds and the mating lasted from 40 to 50 seconds. During the time that the male was going through his preliminary movements, the female was passive, except that she would occasionally and irregularly give her wings a sharp sudden jerk, and move her legs, especially those on the side by the male. This movement was very inconstant.

Two males were observed trying to mate with the same female, though only one was successful, in contrast to what has been observed in *Calopteron juvenile* Gorh., a lampyrid beetle, where five males have been found mating with the same female. A male has also been observed to mate with the same female three times in 20 minutes, and another male was seen to mate with three comparatively widely separated females in the course of half an hour.

Mating has been observed between individuals whose coloration would indicate that they were not more than 12 hours old. It has also been observed that if a female would move during the preliminary stages of the mating the male would wander about aimlessly in search

of her. Attempts to induce mating between individuals of known history were all unsuccessful, due to the nervousness of these individuals when confined.

When confined the adults seem to be positively phototropic and always gather at the side of the cages where the light is brightest. It is perhaps this reaction to light that guides them to the young growth of the tree, but once they reach this growth they invariably gather on the undersides of the leaves and avoid light, for if a shoot on which adults have gathered is turned so that the undersides of the leaves are exposed to strong light the adults immediately become nervous and wander around to the opposite side of such leaves.

The length of life of adults is extremely hard to determine. Kept in glass vials with and without moisture some individuals of unknown previous history have remained alive as long as three days, though the large majority died within the first 36 hours. When allowed to emerge from pupæ on leaves kept in petri dishes individuals have lived as long as four days. Out of large numbers of males and females (approximately 800) on young shoots, brought into the laboratory from the field and placed in water, a few individuals have remained present as long as five days before taking to flight, and on emerging from pupa cases in life-history spirals in the laboratory several females have remained within a few millimeters of the pupa case from which they emerged as long as six days and as short a time as two hours before flying away. Hence, it may be assumed that the life of the adults is at least a week and that it may be as long as 12 days, i. e., by adding the maximum time that they have remained near the pupa case and the maximum time that they have remained on the young shoots.

## TECHNICAL DESCRIPTION.

The following technical description based on material from the Canal Zone has been prepared by Dr. A. C. Baker and Miss Margaret L. Moles, of the Bureau of Entomology.

### EGG.

Plate XI, A.

Size 0.208 mm. by 0.08 mm.; shape elliptical, curved, with the stalk short and attached some distance from the base. Color yellowish, surface apparently without reticulations in some cases and with them in others, due, no doubt, to the structure being destroyed in boiling. When present they average 0.006 mm. in diameter.

### FIRST LARVAL INSTAR.

Plate X, A.

Size averaging 0.304 mm. by 0.192 mm.; shape elliptical, broadest just cephalad of the middle pair of spines. Margin very minutely serrate; abdominal segments distinct but narrow; vasiform orifice oval, almost entirely filled by the operculum. Caudal margin with two pairs of prominent spines, the outer pair measuring 0.032

mm. and the inner pair 0.048 mm. Spines at the vasiform orifice rather short and thick, scarcely 0.032 mm. long. Thorax with a pair of stout, curved spines 0.020 mm. long, arising close to the median line just cephalad of the first abdominal segment. A second pair of spines 0.24 mm. long arising from the cephalic portion of the case near the median line. These are curved evenly backward. While minute teeth are present on the caudal margin, there is no indication of a caudal comb.

Color rather dark brown under the microscope, almost black on the leaf.

### SECOND LARVAL INSTAR.

Plate X, B.

Size averaging 0.4 by 0.288 mm. Shape rather broadly elliptical, broadest across the caudal portion of the thorax. Margin minutely crenulate, caudal comb slightly differentiated. Abdominal segments not very distinctly separated. Vasiform orifice oval, slightly tending to triangular on caudal portion, operculum almost completely filling orifice. Inner pair of caudal spines hair-like, 0.096 mm. long, outer pair minute, spines at vasiform orifice about two-thirds the length of caudal pair. Dorsum with a number of stout, heavily chitinized spines situated as follows: A pair situated near vasiform orifice, each spine about 0.112 mm. long; two pairs somewhat cephalad of these and about equal in length, each spine about 0.144 mm. long; one pair near median line, each spine about 0.064 mm. long; and a pair just cephalad close to medial line, each spine fully 0.192 mm. long. Near the outer margin, slightly more cephalad, is a pair of spines 0.128 mm. long; close to the median line is a pair 0.192 mm. long, and cephalad of this two pairs, the spines about equal in length and measuring about 0.096 mm. Dorsum slightly arched but not prominently so. Color dark brown. The color changes of this and other instars have been treated elsewhere in this bulletin (p. 31 to 36).

### THIRD LARVAL INSTAR.

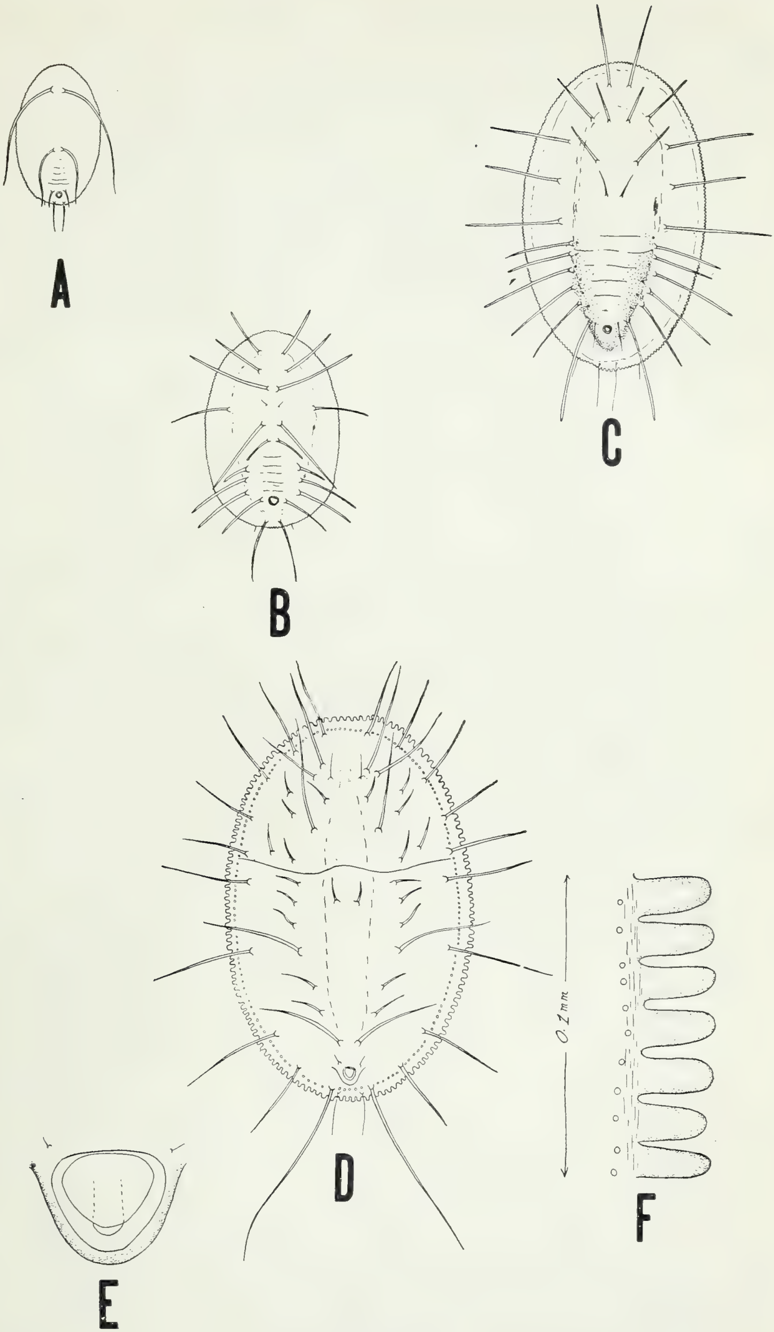
Plate X, C.

Size averaging 0.736 by 0.464 mm.; shape elliptical, broadest just cephalad of middle pair of spines. Margin crenulate; teeth 0.01 mm. in length, 0.007 mm. in width, caudal comb consisting of four marginal teeth slightly larger than the rest. Abdominal segments indistinct, a row of small, closed pores marking terminations of abdominal sutures. Vasiform orifice small, oval, situated on a slight tubercle, operculum cordate, filling three-fourths of the orifice. Lingula not visible. Dorsum with a number of stout spines of varying lengths situated as follows: A pair laterad and cephalad of vasiform orifice, each spine about 0.19 mm. in length; a pair of spines at termination of each abdominal suture, those on segments three and four being the longest. Seven pairs of spines on thoracic portion of dorsum, two short pairs near meson, a longer pair near cephalic margin of case, and four pairs outlining boundaries of thoracic segments of pupa case, the pair nearest to eye spots being 0.24 mm. in length, the pair at dorsal portion of thorax 0.30 mm. in length, the other two short and stout. A pair of long, slender setæ situated cephalad and caudad of the vasiform orifice, and a short, stout pair on the metathorax near the meson. Dorsum slightly arched. Color dark brown.

### FOURTH LARVAL INSTAR OR PUPA.

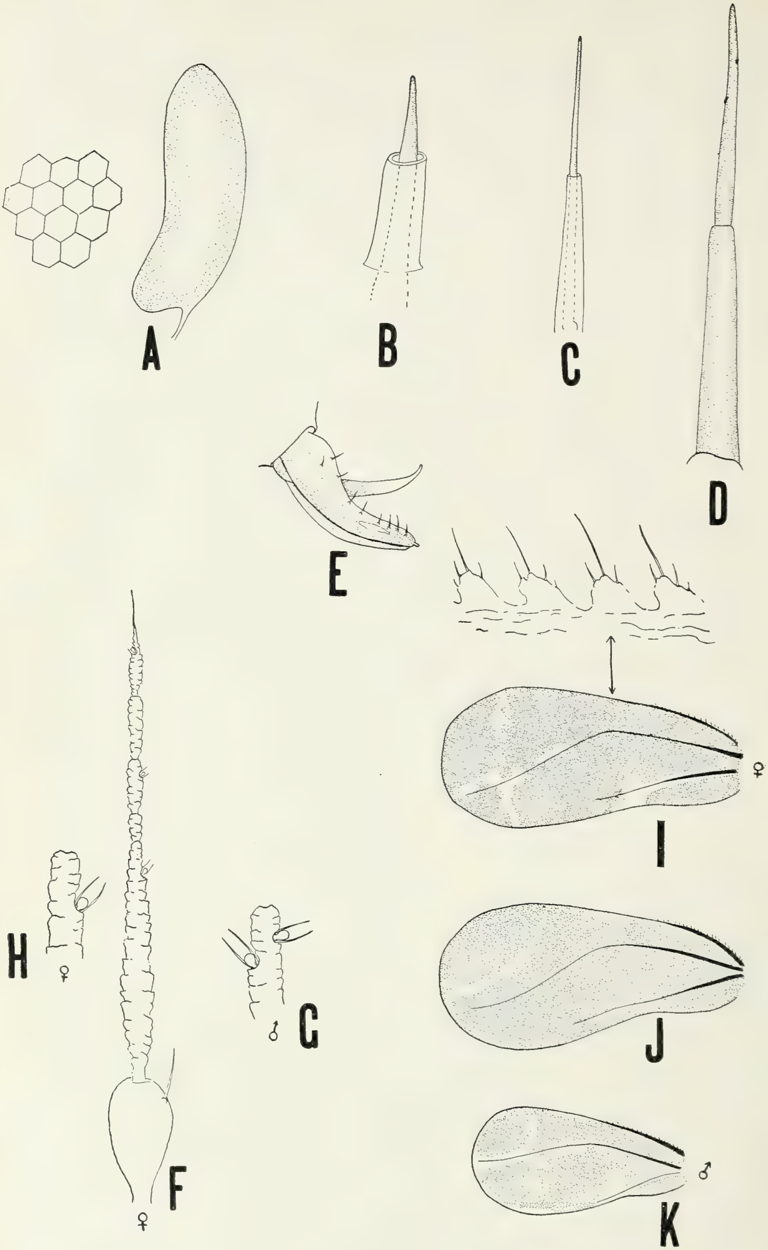
Plate X, D.

Size variable, averaging 1.5 mm. to 0.89 mm.; shape regularly elliptical with dorsum arched; median ridge high, but not markedly distinct from dorsal area, excepting near the caudal portion of abdomen and at vasiform orifice, which is elevated into a more or less prominent tubercle. Color dense black, so much so that even prolonged boiling in potassium hydroxid does not remove the color. When the denser dorsal




THE BLACK FLY.

*A*, Larva, first instar; *B*, larva, second instar; *C*, larva, third instar; *D*, pupa case; *E*, vasiform orifice of pupa case; *F*, margin of pupa case.




THE BLACK FLY.

*A*, Egg, with enlarged view of polygonal markings of egg; *B*, pupal spine immediately after molting; *C*, same, showing variation in outer sheath; *D*, pupal spine just before changing color; *E*, male genitalia; *F*, antenna of female; *G*, distal portion of segment III in the male antenna; *H*, distal portion of segment III in the female antenna; *I*, forewing of adult female showing costal margin at base of wing; *J*, same, showing variations in markings; *K*, forewing of male.

portion of the case is removed the ventral part appears under the microscope as dark brown and more or less irregularly mottled. Submarginal area with usually 20 spines forming a ring, varying considerably in length, but caudal pair nearly always longest. Spines curved outward. A pair of hairs present on caudal margin caudad of vasiform orifice. Spines on dorsum small excepting two pairs on abdomen and three pairs on thorax. (Number and arrangement shown in Pl. X, D.) Vasiform orifice prominent, being on a tubercle, but small and somewhat triangular in shape, tending to circular (Pl. XI, E). Operculum almost entirely fills orifice, obscuring lingula except for a very small portion at tip. Cephalad of orifice a pair of minute setæ is situated, one set on each side. Margin of case dentate, teeth large and bluntly rounded (Pl. XI, F). A space of 0.1 mm. is occupied by six or seven teeth. On this feature alone the case is easily separable from those of the other species. At base of teeth, forming a ring around the case, is a series of minute, clear, porelike areas. On the leaf the case is jet black with the dorsum somewhat arched and the abdominal segments marked, but not distinctly separated. On the margin all around is a narrow cottony lateral wax fringe. This sometimes extends mesad, irregularly covering the submarginal area, but dorsal secretion is usually absent.

### ADULT FEMALE.

Length from vertex to tip of ovipositor 1.12 mm.; color brown, under the microscope a deep wine color with darker shadings on head, thorax, and tip of abdomen. Vertex rounded and possessed of a slight median ridge. Eyes very dark brown. Antennæ (Pl. XI, F) 0.311 mm. in length, segment III 0.117 mm. long, segment IV 0.018 mm., segment V 0.033 mm., segment VI 0.041 mm., segment VII 0.0367 mm. Segments III, V, and VII with a sensorium near the distal extremity of the segment (Pl. XI, H). Labium yellowish, tipped with black. Legs yellowish, shaded on femora with dusky. Femora and tibiæ of the hind legs considerably darker than the others; length of hind femora 0.288 mm.; hind tibiæ 0.432 mm. Tarsi having proximal segment 0.1 mm. and the distal 0.06 mm. Proximal segment armed on its distal extremity with one large spine and several smaller ones; foot normal, with paronychium straight and hairy. Forewings 1.268 mm. long and 0.76 mm. wide at the widest part. Radial sector heavy, yellowish brown in color, and much curved. Cubitus very fine, long and slightly curved, that portion of the wing below it forming a more or less distinct lobe. Wings (Pl. XI, I, J) a deep smoky color, except as follows: A line following the cubitus and a rather large spot near its distal extremity are colorless. A line following radial sector from its distal extremity to almost its median curve and another crossing it almost at right angles are colorless, giving the appearance of a white cross on a dark background. Marking in some wings not so evident, but there is one curved colorless line angling across the wing a short distance above and parallel with the radial sector. Border of this white line more heavily shaded than remainder of wing. Margin of wing armed with a series of rather prominent teeth directed toward the distal extremity of wing. Each one of these armed with one prominent spine and usually three smaller ones (Pl. XI, I, J). The margin formed by these teeth and a line along their bases is bright wine red. Hind wing uniformly smoky, with the vein yellowish brown.

### ADULT MALE.

Much smaller than female, measuring only about 0.79 mm. from vertex to tip of claspers. Antennæ 0.261 mm. in length, segment III 0.117 mm., segment IV 0.015 mm., segment V 0.026 mm., segment VI 0.031 mm., segment VII 0.023 mm. Segment III having two small sensoria near its distal extremity (Pl. XI, G), segments V and VII having only one. Color yellowish or reddish brown. Hind femora 0.24 mm. and hind tibia 0.4 mm. in length. Marked as in female. Claspers 0.126 mm. long. Near their distal ends there are a number of jagged teeth and they are armed

with a number of long, slightly curved hairs, those near the tip being the longest. Penis as long as claspers, yellowish, and almost straight. (Pl. XI, E.) (Forewing, Pl. XI, K.)

Described from females, males, and pupa cases in balsam mounts and pupa cases and eggs on the leaves.

It might not be out of place to discuss here the appearance of the spines during the period immediately after molting. As indicated on p. 35 there are seen on the spines shortly after molting drops of some material, apparently secreted by the spines, which is not seen after the spines have become fully developed and hardened. While we have available no fixed material and are, therefore, unable to make a study of the development of these spines, some information is obtainable from the material in hand which may throw light on the origin of this secretion.

Immediately after the molt the spines may be seen to consist of a distinct outer collar or sheath of about the thickness of the base of the fully formed spine and a central acute portion much narrower in diameter protruding from it. This can be traced through the center of the sheath and some distance beyond its base (Pl. XI, B). In others this outer sheath is more extended, as is also the central core. Here we are unable in the available material to trace the central core beyond the base of the sheath, although it is distinctly traceable within the sheath. (Pl. XI, C.) In somewhat later specimens the spines have reached their full length and we are unable to trace the core through the center of the sheath. Moreover, the portion of the core which extends beyond the sheath is much greater in diameter than in the specimens just discussed, although the line of demarcation is visible (Pl. XI, D). In somewhat later specimens in which the spines have begun to change color we are unable to locate any trace of this former division.

## SEASONAL HISTORY.

From a study of the life-history charts it is evident that the life history is not clear-cut and that under conditions that obtain in the laboratory there is a constant lagging behind in some individuals which becomes most pronounced in the pupal stage. On the basis of the maximum and minimum times for the completion of the life cycle from egg to adult there is the possibility of from three to six generations per year with all sorts of overlapping of generations even from the same colony of individuals. Thus a seasonal history of *Aleurocanthus woglumi* would resemble somewhat that of the asexual generations of some of the plant-lice.

But another factor comes into play and that is the wide difference in the rainfall of wet and dry seasons in the Canal Zone as Table VII shows. This table is for the period during which the work given in this report was done. It is for the Pacific section and is based on

the monthly meteorological reports of the section of Meteorology and Hydrography of the Panama Canal, the observations being made at Balboa Heights.

TABLE VII.—*Weather report for June, 1918, to May, 1919, inclusive, at Balboa Heights.*

| Temperature. | | | Wind. | | | Mean relative humidity. | Rain. | | | Month. |
|---|---|---|---|---|---|---|---|---|---|---|
| Maximum. | Minimum. | Mean. | Prevailing direction. | Hourly average movement. | Maximum velocity and direction. | Per cent. | Rainy days. | Maximum in one day. | Total for month. | |
| °F. | °F. | °F. | | Miles. | Miles per hr. | | | Inches. | Inches. | 1918. |
| 91 | 72 | 80.2 | N. | 6.6 | 23 N | 88.4 | 17 | 1.58 | 5.20 | June. |
| 91 | 73 | 81.6 | NW. | 7.6 | 28 NW | 88.6 | 13 | 1.75 | 5.13 | July. |
| 91 | 72 | 80.8 | NW. | 7.7 | 36 NW | 89.0 | 14 | 1.07 | 3.84 | August. |
| 91 | 72 | 80.8 | NW. | 5.6 | 27 NW | 89.6 | 13 | 2.35 | 7.03 | September. |
| 91 | 71 | 79.8 | NW. | 7.2 | 28 NW | 89.8 | 19 | 2.20 | 9.16 | October. |
| 92 | 70 | 80.2 | NW. | 6.3 | 28 NW | 90.1 | 16 | 2.46 | 9.61 | November. |
| 91 | 71 | 81.0 | N. | 9.4 | 28 NW | 85.6 | 5 | .24 | .55 | December. |
| | | | | | | | | | | 1919. |
| 90 | 70 | 79.8 | N. | 11.5 | 32 NW | 77.8 | 7 | .12 | .28 | January. |
| 94 | 70 | 81.4 | N. | 11.7 | 32 NW | 74.4 | 0 | Trace. | Trace. | February. |
| 92 | 67 | 80.8 | N. | 13.7 | 36 NW | 72.9 | 0 | Trace. | Trace. | March. |
| 93 | 72 | 81.6 | NW. | 9.1 | 31 NW | 80.1 | 15 | 1.42 | 6.43 | April. |
| 92 | 73 | 81.2 | NW. | 6.5 | 30 S | 86.0 | 23 | 1.29 | 5.21 | May. |

With such a radical change in the rainfall it is no wonder that the development of *woglumi* is decidedly checked. Attention has already been called to this under the heading of "Injury," page 18. Out of 12 spirals consisting of 421 eggs on trees exposed to a free play of the wind and started between December 8, 1918, and March 4, 1919, and observed by Mr. Molino, only 245 hatched, 52 reached the first larval instar, 15 the second larval instar, 14 the pupal stage, and 9 the adult stage. Hence, it is no wonder that an incipient infestation observed in Las Sabanas in January, 1919, died out by April of that year.

Furthermore, the citrus trees when not watered during the dry season make little or no growth, and such growth as was uninfested before the beginning of the dry season in places exposed to the wind remained so even on trees that were watered. Such young growth as was made on watered trees also remained practically free.

Likewise the abundance of adults during the dry season is an indication of the seasonal history. During the rainy season there usually is a considerable number of adults present on the young or on the terminal growth of an infested tree. At the beginning of the dry season in December, this abundance of adults shows a decided falling off, few or no adults being present on the terminal growth except for from four to five days following a shower. After a shower considerable numbers would be present, but they would dwindle down to none within three to four days. This was shown on three different

lots of trees under observation. Also during the exceedingly dry months of February (except on Feb. 15 and 16 following a shower on the 11th), March, and the first 14 days of April, practically no adults were found on the trees. But following the first heavy rain of 1.21 inches on April 13, 1919, the adults began to appear on the terminal and subsequent young growth in unusual abundance and continued in such numbers until the end of August. From the foregoing data it seems that what takes place in the laboratory in the life history also takes place out of doors in the dry season, and that at least one generation is lost during that season, making the maximum number of generations that occur in the Canal Zone, at least on the Pacific side, five instead of six.

## PARTHENOGENESIS.

Parthenogenesis occurs in *Aleurocanthus woglumi* just as in other Aleurodidæ whose life history has been studied. Adults from two spirals obtained in the laboratory from unfertilized females have all been males, and in the field, especially at the end of the dry season, a considerable number of colonies were found, all of whose individuals were males. One of these colonies contained 72 male pupæ and another contained 44. Plate VIII, C, shows a colony of 32 male pupæ on a lime leaf. The reason that parthenogenesis occurs more frequently during the dry season is that many adults rarely emerge at any one time, so that those females that emerge during the months of January to April do not have as many chances for fertilization as those that emerge during the rainy season. As has been shown, the chief guiding factor of the males in finding the females and mating is the tendency or habit of large numbers of the sexes to congregate on the young or terminal growth of the trees.

## NATURAL FACTORS THAT TEND TO CONTROL THE BLACK FLY IN THE CANAL ZONE.

There are two natural factors that tend to control the black fly in the Canal Zone and adjoining parts of the Republic of Panama. One is the drying out or lack of rains coupled with increased evaporation due to an increased average monthly wind movement during the dry season. This has already been referred to under "Seasonal history," page 42.

The other factor is the heavy rains that occur during the rainy season. Just after the molting periods and immediately after the emergence of the adults from the pupa cases, the black fly is in a very weak condition and heavy rains coming as they do at a decided angle doubtless wash off large numbers of them. That this actually does take place has been repeatedly observed in all the stages in the life-history work conducted by the authors in the field.

## NATURAL ENEMIES.

So far no internal parasites of the black fly have been found in the Canal Zone or the Republic of Panama, although careful search was made for them.

Several predators on the insect have been found, most of which are coccinellids. These are *Hyperaspis calderana* Gorh. and *H. albicollis* Gorh.; *Scymnus thoracicus* For., *S. horni* Gorh., *S. coloratus* Gorh., and *S. adspersulus* Gorh.; and *Cryptognatha flaviceps* Crotch. Of these the last-named species is apparently the most abundant, but none of the coccinellid predators seems to occur in sufficient numbers to be of any value in controlling the insect.

The larvæ of a lacewing fly (*Chrysopa* sp.) have occasionally been taken feeding on all stages of the black fly. Judging from the number of empty skins of their victims (Pl. IV, fig. 2) that the larvæ carry around with them in the "basket" formed by the long upturned hairs on the margin of the dorsum, these predators, if they occurred in sufficient numbers, would exercise a considerable influence in the control of this pest. These chrysopids are in turn preyed upon by a hymenopterous parasite, specimens of which have been reared from their pupæ.

Several entomophagous fungi have been found to attack the larval and pupal instars of *Aleurocanthus woglumi*. These are *Aschersonia* spp. and *Aegerita webberi* Fawcett. These were taken on heavily infested trees in the Las Sabanas region in November, but were not abundant or well scattered enough so that any faith could be placed in their efficacy as a means of natural control for the insect. Examination, the following April, showed that the fungi had suffered severely during the dry season.

## ARTIFICIAL CONTROL.

Since natural enemies are no factor in the control of *Aleurocanthus woglumi*, artificial control measures, such as spraying with insecticides, must be used. The successful control of this pest by sprays has already been mentioned by Ritchie (33) who used a modified "Florida citrus spray."

Sufficient work on the control of the black fly on a large scale has not yet been done in the Canal Zone to warrant any definite conclusions, but the preliminary control work that has been carried on refutes the idea that such radical measures as were of necessity used in the eradication of citrus canker are necessary to hold this insect in check.

The logical time to spray in the Canal Zone and adjoining parts of the Republic of Panama is in the dry season, as is shown by the meteorological data given under "Seasonal history," page 42. Data on sprays at this time have not been obtained.

Preliminary spray work, however, has been done during the rainy season with 5 and 10 per cent kerosene emulsion, fish-oil soap at the rate of 1 pound to 2 and 4 gallons of water, and nicotine oleate at the rate of 1 part of nicotine to 500 parts of water.

The kerosene emulsion stock solution was prepared according to the following formula: Kerosene, 1 gallon, laundry soap, 10 ounces, and water, 1 gallon. When agitated in an ice-cream freezer or similar device this formula makes an excellent emulsion and has the advantage that it can be readily diluted to any percentage without the use of complicated mathematical formulas. Thus to obtain a 5 per cent solution it is diluted with 18 parts of water since it already contains 1 part of the 19 necessary to make a total of 20.

Both the 5 and 10 per cent emulsions were effective controls though the 10 per cent emulsions caused some burning and were therefore discontinued. The 5 per cent emulsions proved very effective, and trees were completely freed from *A. woglumi* by one or two sprays. If two sprays were used they were given at intervals of one week.

The preliminary tests of fish-oil soap sprays were a decided surprise in that two sprays either at the rate of 1 pound to 2 gallons or to 4 gallons of water at intervals of one week completely freed trees not only of *A. woglumi*, but also of such scale insects as *Pseudaonidia* (*Selenaspidus*) *articulatus* Morg., *Chrysomphalus aonidum* Linn., and *Pseudococcus* sp. without causing injury.

The nicotine oleate was prepared according to the formula given by Moore (20). In the case of this spray it was necessary to apply it three times at intervals of a week before the trees were freed from all stages of the black fly.

Since all this work was done in the rainy season the efficacy of a spray was determined in two ways, (1) by counts made on large numbers of individuals in various stages of development and determining the numbers that were dead and alive, and (2) by the numbers of individuals that would "slough" or wash off during the heavy rains. It was found that when a spray was really effective practically all the dead black flies as well as the scale insects would be washed off during the heavy tropical rains, whereas on check trees or on those where the spray was a failure this did not take place.

The formulas recommended by W. W. Yothers for the control of the citrus white fly (*Dialeurodes citri* Ashmead) have not yet been tried owing to absence of suitable cheap oils of the type he recommends. However, in view of the success that has so far been obtained with both the kerosene emulsions and fish-oil soap sprays, the sprays recommended by Mr. Yothers should prove even more effective due to the fact that their "high boiling point and great viscosity make them operative over a longer period of time after application, and, too, they are only slowly affected by average temperature and showers."

## POSSIBILITY OF THE INSECT BEING INTRODUCED INTO THE UNITED STATES AND FACTORS INFLUENCING ITS ESTABLISHMENT HERE.

The presence of the black fly in Cuba, in the region of Habana, and on the island of New Providence is doubtless a menace from the point of view of the possibility of its introduction into Florida and becoming established there. Theoretically there are several ways that such introduction may take place. The first of these methods is on nursery stock infested with any or all stages; the second is on infested individual plants or parts of plants infested with eggs or pupæ brought in by travelers from Cuba or Nassau; the third, by eggs of the insect laid on fruits; the fourth, by infested parts of plants mixed in shipments of fruits; and the fifth, by adults brought in on freight cars from Cuba via the railroad ferry plying between Habana and Key West. In the case of insects like the Aleurodidæ the stages that are introduced and the conditions under which they are introduced and to which they are subjected after introduction have a decided bearing on whether or not they will be able to maintain themselves and become established.

The first and second of these methods are the ones by which the insect is most likely to gain entrance into the United States and become established here, for the high mortality that takes place, especially in the early stages, means that plants or parts thereof brought into a new locality must be well infested if the insect is to establish itself. This is the way the insect became introduced into Jamaica, Cuba, the Canal Zone and Panama, Costa Rica, and New Providence.

Heavily infested parts of plants will have to be brought in fresh if the insect is to become introduced and established in this manner. The following experiments on the effects of the drying of the pupa cases of the insect on the emergence of the adults show what may be expected from parts of infested plants that have begun to dry out. These will also apply to the possibility of the insect becoming introduced on parts of plants mixed in shipments of fruits.

### EXPERIMENT NO. 1.

Started May 10—Pupal stage.

Number of leaves—Seven leaves used in this experiment. These were kept in a 5½-inch covered petri dish. (Lime leaves.)

Number of pupæ—100 males and 200 females. Adults had been previously emerging from same colonies.

Remarks:

May 11—Two males and two females emerged.

May 12—Six males and eight females emerged.

May 13—Three males and six females emerged.

May 14—Two males and three females emerged.

May 15—Five males and six females emerged. Individuals having trouble getting out of pupa cases, due to dryness.

Remarks:

May 16—Two males and two females emerged. One female unable to free itself from pupal skin. Died.

May 17—Two males and one female emerged. One male died in attempts to free itself from pupal skin.

May 18—No observations.

May 19—One male and one female emerged. One male and one female died in attempting to emerge on May 18 (?). Leaves thoroughly dried out. They were very dry May 15.

May 20—No emergence. A blotter was moistened with water and two drops of phenol put on it before it was placed in petri dish with leaves.

May 21—No emergence. A number of pupæ looked normal, and further emergence was considered possible.

May 27—Entire lot of leaves moldy. No further emergence, hence whole lot discarded and experiment finished.

### EXPERIMENT NO. 2.

Started May 28, 1919—Pupal stage (early).
Number of leaves—Six, placed in petri dish, covered.
Number of pupæ—200 females, 50 males. No previous emergence.
Remarks:

June 4—Leaves drying out, but not thoroughly dry. No emergence.

June 6—Leaves thoroughly dry. No emergence.

June 13—No emergence.

June 15—No emergence.

June 17—Pupæ carefully examined. Shriveled. All dead. Experiment discontinued.

### EXPERIMENT NO. 3.

Number of pupæ—23 males and 32 females.
Leaves kept from May 11, 1919, to June 26, 1919, in bottle of water.
Remarks:

June 26—One male emerged. Leaves badly wilted since June 23.

June 30—One male emerged.

July 4—One male emerged. Shoot all dried up, barely moist; leaves removed and put in covered petri dish for further observation.

July 5—One female died in process of emergence. Moisture added to petri dish.

July 6—One female died in process of emergence.

July 8—One female emerged. One female died in process of emergence. Leaves thoroughly dried out.

July 9—Leaves thoroughly dried. No further emergence. All pupæ examined and dead. Experiment discontinued.

### EXPERIMENT NO. 4.

Number of pupæ—35 females and 46 males. Brought in from field. 15 males and 2 females had already emerged.
Started June 5, 1919—Put in petri dish.
Remarks:

June 6—Four females and three males emerged. All in the morning.

June 7—Four females and two males emerged. All in the morning.

June 8—One female emerged in morning.

Remarks:

June 9—Two females and two males emerged. All in the morning.
June 10—One female and one male emerged. Both in the morning.
June 11—No emergence; leaf thoroughly dry.
June 12—One female emerging. T-shaped slip on pupa visible, but individual having trouble, due to dry conditions. Moisture added to petri dish.
June 13—One female of June 12 died in emergence. T-shaped slit slightly spread open, indicating feeble attempt of individual to escape.
June 14 to 20—No further emergence. Pupæ all dead on examination. Experiment discontinued.

###### EXPERIMENT NO. 5.

Number of pupæ—87 females and 18 males, from which 3 females and 2 males had emerged before these were brought to the laboratory on June 5, 1919, and were put in a petri dish.

Remarks:

June 5 to 9—No emergence. Leaves very dry on June 9.
June 10—One male emerged in morning.
June 11—No emergence.
June 12—One female emerging in morning. Moisture added.
June 13—Female emerging June 12 died in process.
June 14 to 20—All pupæ dead on examination June 20. Experiment discontinued.

The third of the methods outlined, namely, the bringing in of eggs on the fruits, seems to be a rather remote one. That the adults do lay eggs on the fruits under certain conditions has been demonstrated by Morrison (1917) and by the writers, and though the writers have failed to find this the case out of doors in the region where they have worked, they fully realize that it may take place. But the first-instar larvæ of *A. woglumi* are not like the larvæ of scale insects, as has been shown under the heading "Life history," p. 31. They are sluggish crawlers and have little ambition to wander far from the eggs from which they have hatched. Hence, even if the eggs on fruit would hatch the larvæ would either settle down on it or, if they fell off, would perish. The following experiment shows how remote the possibility of the insect being introduced in the egg stage and becoming successfully established really is.

In order to see if larvæ would migrate far the following experiment was tried: Two leaves bearing about 200 eggs each, from which larvæ were just beginning to hatch, were removed from a twig and tied to two leaves on a young tree in the laboratory. One was tied so that parts of its under surface rested against the under surface of the leaf on the tree and the other was tied so that its under surface rested against the upper surface of the leaf on the tree. Five days later, when the leaves bearing the eggs had completely dried out, an examination was made, and it was found that only four larvæ had crawled

over to the under surface of the leaf of the tree and only three had settled on the upper surface. On the two leaves that were tied to those on the tree a total of 65 larvæ had settled. An equal number were dead attached to the eggs, apparently having died in the attempt to escape from them, because of the drying out of the leaves, as is shown later. A week later all the larvæ that had migrated to the tree were dead.

In order to show the effects of the drying out of the leaves on the hatching of the eggs the following experiments are of interest:

#### EXPERIMENT NO. 1.

On July 12, 1919, a shoot on which adults were clustered was brought to the laboratory. Fifteen spirals were laid on three upper leaves of the shoot and ten on two lower ones. The shoot was placed in a bottle of water for observation.

In the 15 spirals were 387 eggs. In the 10 spirals were 187 eggs.

On July 23, 1919, the entire shoot was wilted, the upper leaves were not dry, but the lower ones were turning brown and drying out. These leaves were removed and put in covered petri dishes for observation.

On July 26, 1919, 340 out of the 387 eggs hatched (approximately 90 per cent), but only 30 of the 187 eggs had hatched on July 30 and the experiment was discontinued.

#### EXPERIMENT NO. 2.

Eggs on leaves brought into laboratory from the field July 23, 1919, still whitish in color, hence not over 24 hours old. Put in covered petri dish. Number of eggs, 71.

July 26—Eggs fully colored.

July 28—Leaves drying out.

August 1—Leaves thoroughly dry, eggs shriveled. Discarded.

#### EXPERIMENT NO. 3.

Eggs on leaves brought into laboratory from the field July 23, 1919; blackish in color, indicating that they were over 8 days old. Put in covered petri dish. Number of eggs, 335.

July 26—Eggs shriveling. Leaves wilted but moist.

July 28—Leaves drying out; no hatching.

August 1—Eggs shriveled. Leaves slightly moist. Discarded.

#### EXPERIMENT NO. 4.

Eggs on leaves brought into laboratory from field July 23, 1919; eggs dark brown in color, indicating that they were at least 3 days old and not more than 10 days old. Number of eggs, 173.

July 26—No hatching. Leaves wilted but moist.

July 28—No hatching. Leaves drying out.

August 1—Eight larvæ died in emerging. Rest of eggs shriveled. Leaves slightly moist. Discarded.

#### EXPERIMENT NO. 5.

Eggs on leaves brought into laboratory from field July 23, 1919; eggs brown in color, indicating that they were over 3 days old. Number of eggs, 141.

July 26—No hatching. Leaves wilted but very moist.

July 28—No hatching. Leaves drying out.

August 1—No hatching. Eggs shriveled. Leaves still slightly moist. Discarded.

The fifth possible means of introduction, namely, the bringing in of adults on freight cars from Cuba via the railroad ferry plying between Habana and Key West, is one worthy of consideration. The writers have seen what they believe to be "train borne" infestations at Miraflores and Frijoles, though there is no proof, except that all other possibilities were eliminated as far as practicable. In the first place, the infestation in the Canal Zone could be "train borne" much more easily than it could be carried from Cuba to Florida. Frijoles is about midway between Panama and Colon, or about an hour's run by train, while Miraflores is but 15 to 20 minutes distant from Panama. On the other hand, Habana is over 10 hours away from Key West with all the trip across the ocean. Whether the adults could weather such a trip is open to question. Again, in the Canal Zone the "train borne" infestation took place in a region where the insect had already successfully established itself. Doubtless if introduced at Key West or at the lower end of Florida, the black fly would, under proper conditions, become established, but whether it would be able to maintain itself in the more northern portions of the State is debatable for here there is a factor with which the writers have not had any experience in the Canal Zone or adjoining parts of the Republic of Panama. That factor is much lower minimum and mean minimum temperatures than are ever reached in the regions where *A. woglumi* now occurs.

Then too, if only unfertilized females were introduced the insect would die out after the first generation, for owing to parthenogenesis all the individuals would be males. And finally, the question of the influence of different climatic conditions, other than temperature, on the mortality in the various developmental stages of the insect comes into play. All in all there is at present nothing to warrant the idea that there is great danger of *Aleurocanthus woglumi* becoming introduced into and established in the United States through adults brought from Cuba on freight cars via the railroad ferry plying between Habana and Key West. The matter is one where there are two points of view. The removal of citrus and other host plants from the vicinity of the terminal freight yards and railroad sidings in Habana, however, would absolutely insure freight cars being free from *A. woglumi*.

In conclusion, the method by which the black fly is most apt to become introduced into the United States and through which it will have the greatest opportunity of becoming established in favorable localities, is on undefoliated, infested nursery stock of various kinds, or individual infested plants for ornamental or other purposes. This includes also undefoliated parts of plants like cuttings for propagation. This is the way it has spread from the Tropics of the Old World to those of the New and the way it has continued its spread over widely separated parts of its new home. Bragdon (5) has pointed out the

danger of the black fly being brought in on parts of infested plants by passengers returning from a country where the pest occurs.

## SUMMARY.

The black fly, *Aleurocanthus woglumi*, was introduced into Jamaica from India on infested food plants within the last 10 to 15 years. From this focus in the New World it has spread to Cuba, New Providence, the Canal Zone, the Republic of Panama, and Costa Rica, and is continuing its spread from these new centers.

It was probably introduced into the Canal Zone between the years 1912 and 1914, the introduction taking place on more than one lot of infested food plants.

This report is based on an intensive study of this pest in the Canal Zone made from June, 1918, to August, 1919.

The introduction and establishment of this pest in widely separated areas has taken place through nursery stock or infested individual food plants, including cuttings for propagation. Within a region this method of spread is supplemented by the natural flight of the adults, by their carriage on vehicles and trains, and on the clothing of persons passing or working among infested trees.

The important food plants of this insect in the Canal Zone are: *Ardisia revoluta*, various species of the genus Citrus, *Coffea arabica*, *Eleais melanococca*, *Eugenia jambos* and *E. malaccensis*, *Lucuma mammosa* and *L. nervosa*, *Melicocca bijuga*, and *Mangifera indica*.

This insect, under certain conditions, injures seriously plants infested by it, but no plants killed by it have been found in the Canal Zone and Republic of Panama.

There are six stages in the life history of the black fly, namely, the egg, three larval instars, the pupa, and the adult. The life history is not clear-cut and there is a decided overlapping of stages. The length of time for the completion of one generation ranges from 45 to 113 days. The duration of the various stages are: Egg, 11 to 20 days; first larval instar, 7 to 16 days; second larval instar, 5 to 30 days; third larval instar, 6 to 20 days; pupa, 16 to 80 days; adult, probably 6 to 12 days.

There is a great mortality in the various stages, only 22.5 per cent of the individuals of 790 eggs reaching maturity.

The natural climatic factors that tend to hold the insect in check in the Canal Zone are: Drying out during the dry season and the heavy rains during the wet season.

Five species of coccinellids and one species of Chrysopa have been found to be predacious on the various stages of *Aleurocanthus woglumi* but they are not as yet sufficiently abundant to be important factors in its control. No internal parasites were found.

The black fly can be controlled by contact insecticides. Five and ten per cent kerosene emulsions, fish-oil soap at the rate of 1 pound to 2 and to 4 gallons of water, and nicotine oleate have given good results.

There is a possibility that this insect may gain entrance into and become established in the United States, particularly Florida. It already occurs in Cuba and Nassau, New Providence. The way in which it is most apt to be introduced and become established is through infested food plants, such as nursery stock or individual plants, or as cuttings for propagation. This is the way in which it was brought from the Old World to the New and is the way in which it is continuing its spread to widely separated parts of its new home.

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